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COMMITTEE ON THE PEACEFUL USES
OF OUTER SPACE

PROGRESS OF SPACE RESEARCH 1988-1989

Report submitted by the Committee on Space Research of the International Council of Scientific Unions

Note by the Secretariat

Annexed hereto is a report on the progress of space research in 1988-1989, submitted by the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) in accordance with the request of the Scientific and Technical Sub-Committee for the submission of reports by COSPAR on scientific and technological developments in the exploration and peaceful uses of outer space. The report is being circulated, as received, only in the language of its submission (English).

Annex

COSPAR

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PROGRESS OF SPACE RESEARCH

1988 - 1989

REPORT SUBMITTED BY THE

COMMITTEE ON SPACE RESEARCH (COSPAR)

OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS (ICSU)

November 1989

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FOREWORD

The following report giving information on progress in the various disciplines of science involved in space research was prepared by COSPAR in response to a request from the Scientific and Technical Sub-Committee of the United Nations Committee on Peaceful Uses of Outer Space. The report has been constructed so as to reflect the scientific fields of the seven COSPAR Interdisciplinary Commissions and two Panels.

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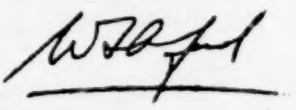
May I take this opportunity of expressing my gratitude to the aforementioned as well as to the other distinguished scientists who submitted information for the preparation of this report.



November 1989

William Ian Axford
COSPAR President

CHAPTER 1

SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY, AND CLIMATE

1. Polar-Orbiting Environmental Satellites

a. People's Republic of China

China successfully launched its first experimental polar-orbiting satellite, FY-1, from a launch site in Taiwan, Shanxi province at 05:30 Beijing summer time on 7th September, 1988, using a new Long March 4 booster rocket. The satellite was a three-axis stabilized polar-orbiting platform in a sun-synchronous orbit. By early October 1988, the FY-1 satellite had obtained large amounts of experimental data. After a certain time this experimental stage was expected to proceed to an operational trial period. Two weeks after launch a degradation in the response of the IR sensor (10.5 - 12.5 μm channel) was noted. Following a loss of control in orbit, the satellite ceased operations in November 1988.

The principal payload of the satellite was a multi-spectral scanning radiometer which provided raw image data from three visible channels, one near-infrared channel and one infrared channel. Various image products including digital land and ocean remote sensing products were planned to be derived from the raw data by a dedicated ground receiving and processing system. The communication equipment on board the satellite performed real-time broadcasts of High Resolution Picture Transmission (HRPT) and Automatic Picture Transmission (APT) data. The data formats of HRPT and APT were designed to be compatible with those of the NOAA satellites.

b. USSR

The USSR continues its meteorological programme on Meteor satellites. A vertical sounder is being flown on the Meteor. In a joint project of groups from the USSR, France, and Federal Republic of Germany a radiometer (Sca Ra B) to measure the planetary radiation budget parameters is being built. It is scheduled for launch in fall 1991 on board one of the Meteor satellites.

c. France

The Centre National d'Etudes Spatiales (CNES) announced on July 21, 1989, that the French government had approved Phase C/D funding for SPOT-4. Final development and construction will begin immediately. The spacecraft is expected to be ready for an Ariane-4 launch as early as 1994, which is estimated end of lifetime for SPOT-3.

The SPOT-4 design differs from the earlier SPOT series (SPOT-1/2/3) in the following aspects: five year lifetime design as opposed to three years; a new extended platform design; new on board magnetic tape recorders enabling the 10 and 20 meter resolution data to be co-registered on board the satellite instead of on the ground; and the addition of a middle infrared band to the standard SPOT sensors for improved vegetation analysis capability. The wide-field vegetation instrument planned for SPOT-4 was cancelled.

In addition to the established SPOT program cooperation with Belgium and Sweden, the European Space Agency (ESA) and CNES will launch a joint experiment on SPOT-4 called "PASTEL." PASTEL is a prototype high data transmission system using lasers.

d. Europe

The European Remote Sensing Satellite (ERS-1) is on schedule for a launch in 1990. Instruments include active and passive microwave devices and an infrared radiometer. The launching of a second satellite of the same or similar payload in 1994 is still under critical consideration but may be delayed one or two more years. Analyses of expected ERS-1 data are underway with theoretical and field simulations. In particular, airborne experiments are being conducted to measure radar windspeeds and wave heights over the oceans. Altimeter data of the American satellite GEOSAT are also the subject of intensive analyses. Thus a longer time series could be continued by the altimeter on board ERS-1.

e. United States

1) Current

The year 1989 marks the tenth year of operational atmospheric sounding production from NOAA's operational sun-synchronous polar orbiting environmental/meteorological satellites. NOAA-11 is in an afternoon ascending orbit and NOAA-10 is in a morning descending orbit. NOAA-11 was launched on September 24, 1988, from Vandenberg Air Force Base and operationally replaced the aging NOAA-9 spacecraft on Jan. 3, 1989 (the NOAA-9 HRPT direct readout is still functioning). The NOAA-11 instrument complement consists of Advanced Very High Resolution Radiometer/2 (AVHRR/2), High Resolution Infrared Radiation Sounder/2 (HIRS/2), Search and Rescue (SAR), Solar Backscatter/2 Ultraviolet (SBUV/2 data are still being processed from NOAA-9 to establish an overlap with NOAA-11), the French provided Argos Data Collection and Location system, Microwave Sounding Unit (MSU), and the Stratospheric Sounding Unit (SSU). NOAA will continue to collect data from the SBUV on NOAA-9 as long as possible. The imagers, sounders, and the Earth Radiation Budget Experiment (ERBE) on NOAA-10 (the SSU is not on board), continue to operate in a satisfactory manner, although the SAR failed on September 8, 1988.

The Polar-Orbiting Environmental Satellite (POES) series will continue to operate through at least the mid to late 1990's (through the NOAA-K, L, and M satellites). Starting with NOAA-K, the MSU and SSU will be replaced with an Advanced Microwave Sounding Unit (AMSU-A1, A2, and B). Product processing software is currently in the design/development phase for this spacecraft system. NOAA-K is currently scheduled for launching in December 1993.

Data from the Special Sensor Microwave/Temperature (SSM/T) instrument on board the Defense Meteorological Satellite Program (DMSP) satellite series is being processed into sounding products by NOAA. Currently the two DMSP polar-orbiting satellites, F8 and F9, are both in morning ascending equator crossing configurations.

2) Future

High-definition soundings for large-scale numerical weather prediction are a central focus of NOAA and NASA plans for post NOAA-N polar orbiting satellites. Augmenting the Advance Microwave Sounding Unit to upgrade sounding resolution and reduce temperature errors will be a combination of an improved imager (AMRIR) and a NASA-developed myriad-channel spectrometer sounder called AIRS (Atmospheric Infrared Sounder). While AIRS will fly on the NASA Polar Platform (and perhaps a European Platform as well), NOAA will undertake the software development to make AIRS data available to operational data users in quasi-real time. In the mix of instruments, AMSU provides useful soundings in full cloud-covered areas and otherwise supplements all infrared sounding data. AMRIR surpasses NOAA's current imager (AVHRR) in its ability to seek out cloud-free holes in partly-cloudy regions, through which AIRS may operate. (It also carries back-up sounding and surface-temperature channels.) AIRS, through its thousands of narrow-spectral channels, combines with microwave sounding data in clear areas to produce a high definition sounding with improved calculation of cloud height. AIRS, AMRIR, and AMSU are expected to deliver soundings with data points spaced no more than 1 km vertically and with errors no more than 1 deg. K.

2. Space Station Polar-Orbiting Platform Programme

NASA, ESA, and Japan finished the evaluation of more than 200 proposals for the Earth Observation System (EOS). These led to definitions of very excellent research programmes which are centered around the various proposed experiments and should also provide a basis for thorough analyses of their data. The launch of the first platform is scheduled for about 1995.

3. Geostationary Environmental Satellites

a. Japan

Geostationary Meteorological Satellite Number 4 (GMS-4) was successfully launched by Japan's National Space Development Agency (NASDA) on September 6, 1989, on an H-1 launch vehicle from Tanegashima Space Center. All flight programs of the H-1 launcher were accomplished, and the satellite was separated from the third stage almost 30 minutes after lift-off. Apogee motor firing was conducted through command transmission from the Tsukuba Tracking and Control Center. GMS-4 was placed into a verification orbit at 160 degrees E on September 2nd, then will be moved to its final operational station at 140 degrees E in December, 1989. NASA assisted NASDA's GMS-4 launch with tracking and data acquisition. All NASDA satellites are named after flowers; GMS-4 is "Himawari-4" (Sunflower-4).

Japan has started the development of GMS-5, which is to be launched in 1994. The new satellite will add a water vapor channel to the existing imaging channels. The wavelengths of the modified instrument will be 0.55-0.90 μm in the visible channel, 10.5-11.5 μm and 11.5-12.5 μm in the infrared window channel, and 6.5-7.0 μm in the water vapor channel.

b. People's Republic of China

The People's Republic of China (PRC) is now seriously considering the development of a geostationary meteorological satellite system. At present the programme is in the stage of system design. It is planned to have an experimental geostationary meteorological satellite launched in the mid-1990's. Development work will be carried out with higher priority than that for the continuation of the polar orbiting satellite (FY-1) programme.

This first experimental geostationary meteorological satellite system will comprise five parts, a geostationary meteorological satellite called FY-2, a launch vehicle, a launch facility, a tracking and control centre, a command and data acquisition station and a data processing centre.

Since facilities for satellite launch, tracking, and control are now well established in the PRC, special attention is now being paid to the development of the FY-2 satellite itself, the command and data acquisition station, and the data processing center. The data acquisition and processing system will be multi-functional and capable of real time operations, and will include a Command Data Acquisition Station (CDAS), a Data Process Center and System Operational Control Center (DPC-SOCC), Ranging stations (one primary station, two secondary stations), widely dispersed Data Collection Platforms (DCP), Mid-range Data Utilization Stations (MDUS) and Small-range Data Utilization Stations (SDUS), WEFAX or cloud image receiving stations, and a ground communication system.

The satellite will perform the following main tasks:

- remote sensing
- cloud picture broadcasting
- data transmission, data collection and relay
- satellite telemetry and command functions
- attitude and orbit control.

The location of the FY-2 satellite is planned to be between 105 and 110 degrees East longitude.

c. United States

The next U.S. GOES satellite to be launched (GOES-I) will be the first in a series of five 3-axis stabilized spacecraft that will have the capability to provide simultaneous imaging and sounding data. The design and development of the temperature/humidity sounding product processing software system is currently underway. GOES-I is scheduled to be launched in December, 1990. Geostationary data user requirements for the post-GOES M period were solicited by NOAA at a workshop held Jan. 10/11, 1989.

Briefly stated, users requested smaller fields of view than are to be delivered by GOES-I/M, more flexibility in scheduling repeated local views of severe storm regions versus large regional views from which cloud-drift wind values are derived, and a next-generation temperature and moisture sounder. Improved soundings would be obtained from data from an interferometer-type instrument with a potential for hundreds, even thousands, of ultra-narrow spectral channels (versus the present system utilizing one-to-two-dozen filter-selected channels.) Data requests have been provided to a GOES-N Phase A Study group at Goddard Space Flight Center for evaluation. Goddard's study team in turn cooperates with a Phase-A study group at Marshall Space Flight Center considering a payload for NASA's Geostationary Platform. The Geostationary Platform is expected to carry NOAA geostationary instruments as support to a suite of NASA-developed high-capability experimental instruments for special Earth-sensing tasks.

d. India

During the 1990s an INSAT-II series of geostationary telecommunications/meteorology satellites will replace the currently operational INSAT-I satellite system. The construction of the first two satellites of the INSAT-II series is already well advanced. The first INSAT-II satellite is expected to be launched during late 1990 and a second in late 1991 using Ariane launch vehicles. Present plans call for three more INSAT-II satellites.

INSAT-II satellites will be multi-functional and three axis stabilized but will be larger and much heavier than those of the INSAT-I series. The new Indian built radiometer will have horizontal resolution of 2 km in the VIS channel and 8 km in the IR channel.

The current 401 MHz data collection transponder will be continued, but INSAT-II will also carry a 406 MHz Search and Rescue (SAR) distress alert transponder to aid the international satellite (COSPAS/SARSAT) search and rescue programme.

4. Tropospheric Research and Applications

a. Clouds

Clouds affect most intensively the energy transfer by radiation within the atmosphere. Therefore the ISCCP (International Satellite Cloud Climatology Project) started very early (1983) to analyze cloud data measured over the entire Earth. This project of the World Climate Research Programme (WCRP) is to be continued until at least 1993, covering a time period of ten complete years. At present the data of more than three years (1984-1988) have been analyzed. Several regional experiments, e.g. FIRE (First ISCCP Regional Experiment of the USA), ICE (International Cirrus Experiment of Western Europe), and others have taken place. Numerical and experimental studies have been made of processes important for the maintenance of clouds and of their radiative properties in order to develop parameterized schemes for extended numerical climate forecasts. Many research groups (in the USSR, Hungary, Poland, USA, India, Japan, China, and other countries) use satellite images for very detailed analyses of cloud structures and statistics. The WCRP supported a project to identify clouds in satellite images measured over both polar regions where they usually show a low contrast. This project concluded that clouds can be measured there only if additional information on their spectral reflectance and emittance are available, as, for instance, provided by the 3.7 μm channel of the AVHRR.

In the United States, the development of a generic cloud algorithm, which uses multi-spectral data from the AVHRR has accomplished the following: a daytime algorithm for the global detection of clear-sky, mixed and cloudy image (2x2 pixel) arrays for both ocean and land

surfaces was developed. An algorithm was developed which computes the albedo in channel 3 (3.7 micrometers) and which is being used in the detection of clouds over snow and ice covered surfaces. A validation capability was developed with an image processor using Local Area Coverage (LAC) (1 km) resolution AVHRR data.

The GOES VAS (Visible Infrared Spin Scan Radiometer Atmospheric Sounder) North American cloud climatology, prepared by NOAA, has now accumulated statistics from over three years. GOES/VAS multi-spectral observations in the carbon dioxide absorption band at 15 microns have been used to calculate both cloud top pressures and effective cloud amount. The technique reliably distinguishes semi-transparent cirrus from opaque clouds. Seasonal and diurnal characteristics of the data have been catalogued. Correlations with outgoing longwave radiation are underway.

b. Severe and Tornadic Storms

NOAA research based on geostationary satellite imagery and research aircraft flights is helping to explain why a storm produces intense tornadic activity. GOES imagery has revealed that thunderstorms interacting with low level convergence boundaries have a high potential for producing tornadoes and severe weather. Such boundaries are often detectable in satellite imagery as either well-organized convective cloud lines (arc cloud lines) separating the rain cooled air from surrounding low level cumulus cloudiness or as the transition zone between a region of low level wave clouds and the cumulus cloudiness. Research aircraft investigations of arc cloud lines show that the flow of air associated with those boundaries is characterized by both strong wind shear and intense upward motion. When such boundaries are acted upon by the updraft of a strong thunderstorm, intense tornadic activity is often the result.

c. Atmospheric Soundings

The United States continues to support the operational production of atmospheric temperature, water vapor, and ozone products from both NOAA-10 and NOAA-11 as well as temperature soundings from the USAF's DMSP F8 and F9 satellites. A Minimum Variance Simultaneous (MVS) physical retrieval algorithm (for temperature and water vapor) was implemented in September, 1989. Research and development is currently underway on several algorithms which will calculate improved TOVS "first guess profiles". In addition, data from the Special Sensor Microwave/Imager (SSM/I) on board the DMSP spacecraft will be ingested and calibrated for inclusion in the sounding product processing by mid-1990.

d. Sounding Software

The International TOVS (TIROS Operational Vertical Sounder) Processing Package (ITPP) developed and distributed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in the United States has been the main vehicle for testing and developing retrieval techniques at over 40 research centers in 20 countries. The ITPP has been packaged into a modular form to facilitate the addition of recent improvements or local adjustments. It is available from CIMSS upon request.

The ITPP is currently working with two versions. Version 3.3 was released in February, 1989, and has

(1) navigation software upgraded by implementation of Brower-Lyddane model,
(2) NOAA-11 capability provided in the form of new coefficients and minor software modifications.

Version 4.0 is expected to be released in October, 1989 and will have

(1) linearized radiative transfer equation solution with "dry" and "wet" transmittance separation,
(2) dynamic tuning with regression estimation of deltas from MSU observations while gammas and epsilons remain fixed,
(3) improved treatment of cold surfaces through inversion detection with cold shortwave brightness temperature check,
(4) use of cold blackbody for HIRS calibration under conditions of extremely low temperature and humidity such as found in Antarctica,
(5) corrections to high latitude TOVS geometry, and
(6) documentation based on U.S. Navy Environmental Prediction Research Facility (NEPRF) standards.

e. Baseline Upper Air Network

American scientists are participating with WMO personnel in the generation of a final report on the Baseline Upper Air Network (BUAN) feasibility test conducted from January 15, 1988, through July 15, 1988. This test was performed to measure the impact on sounding accuracy of a small high quality sample of radiosondes launched to coincide in time and space with satellite overpasses. It is expected that this final report along with archived data will be available by mid-1990.

f. International Use of Weather Satellite Data

Within several countries new satellite receiving stations have been installed. Data, primarily imaging data of polar-orbiting and geostationary satellites, are subject to thorough interpretation for the purpose of weather forecasts and climate research. In Poland, for instance, special efforts are underway to put some of these data into IBM-PC systems and storage devices for easy use by other offices and agencies with small computing power. Now many countries utilize the TOVS data to improve their weather forecast systems using software packages developed in the USA for small inexpensive computing facilities. In the USSR and also in Hungary intensive work continues on the analyses of humidity and surface radiation budget parameters. Particular attention is now being paid to derive measures of the evapotranspiration at the surface for direct applications in agriculture and forestry.

g. Earth Radiation Budget

The Earth Radiation Budget Experiment (ERBE) of the United States is still continuing. It is complimented by an extensive analysis of the AVHRR-imaging data of NOAA orbiting satellites. These latter data, in particular the outgoing longwave radiation (OLR), are used in operational analyses of precipitation probability and circulation anomalies in the tropics.

Collocated AVHRR, HIRS, and Earth Radiation Budget Experiment (ERBE) data from the NOAA-9 satellite have been utilized to obtain preliminary algorithms for improving the calculation of outgoing longwave radiation (OLR) and albedo from narrow band observations. For the albedo, both channels 1 and 2 of the AVHRR are used, while channel 5 only is used for the OLR. An algorithm for obtaining the OLR from four channels of the HIRS was developed and is being tested. Results so far indicate that the RMS error is greatly reduced compared with that obtained from the single channel from the AVHRR. A set of system simulations has been performed to evaluate candidate scanner configurations to fly as part of the Earth Radiation Budget Instrument (ERBI) on the Polar Platform during the 1990's.

The proposed CERES instrument involves both types of scanners. The shortwave, longwave, and net effects of clouds on the Earth's radiation budget (cloud forcing) have been estimated from the Nimbus-7 ERB and CLOUD data sets. The annually-averaged net radiative effect of clouds is that the Earth is cooled by about 27 W/m2. This net cooling results from the combined effects of longwave cloud-radiative warming of 24 W/m2 and shortwave cloud-radiative cooling of 51 W/m2. The annual globally averaged cloud amount for the study period was 52%. This implies, if all other cloud properties remain invariant, that a 1% increase in global cloud cover would correspond to a 0.5 W/m2 decrease in net radiative heating of the Earth.

h. Surface Radiation Budget

Analysis schemes to determine the Surface Radiation Budget components at the Earth's surface from satellite imaging and sounder data are now used in several countries. Of prime interest has been the determination of downward solar radiation for purposes of solar energy use and also for estimations of evapotranspiration over land surfaces and of the ocean heating. In one project, SUNSAT, which is primarily sponsored by the European Economic Communities, the solar radiation reaching the whole African continent is calculated with a spatial resolution of 32 to 40 km. In another, the downward solar radiation is computed from GMS-B1 data over the entire southern-eastern part of Asia with a spatial resolution of about 10 to 30 km. In several countries the Earth Radiation Budget components at the surface are also calculated from satellite data, but at a smaller spatial scale for direct operational use.

i. Aerosols

There has been some progress in developing aerosol remote sensing capabilities with AVHRR data over the oceans of the Earth over the past year. New radiance/aerosol optical thickness tables were developed at NOAA which are appropriate for the orbit of NOAA-11, with its 0130 pm ascending equator crossing time. A radiance offset term was developed for channel 1 of AVHRR. This term corrects for instrument calibration errors and radiative transfer modeling errors. Archiving and distribution of the experimental operational aerosol products was initiated by NOAA/NCDC in Asheville, NC.

5. Middle Atmosphere

There has been remarkable progress in the middle atmosphere (especially stratosphere) research in the past few years. Significant advances have been made in our understanding of the impact of anthropogenic activities on the Earth's ozone layer. Since the signing of the Montreal Protocol there is more evidence available that the chlorine and bromine containing chemicals can be responsible for a substantial depletion of stratospheric ozone over the Antarctica.

At present the only reliable satellite observations that can be used for the determination of ozone changes in the upper stratosphere are those of SAGE I and II.

For a six year average observational period, 1980-1986, of the latitude regions 20-50°S, the comparisons between SAGE II and I indicate:

- a decrease in ozone between 35 and 44 km altitude with a maximum ozone change at 40 km of -3 (+ or - 2%).
- a decrease in ozone at 25 km of the order of -3 (+ or - 2%).
- zero change in ozone at 28-33 km and at 45-48 km.

In the upper stratosphere, the available satellite observations of temperature are for a period of less than a solar cycle. Nevertheless, these observations for the period (1985-86) - (1979-80) indicate a global temperature change of -1.5 (+ or - 1 K.). This temperature change is compatible with the observed ozone changes at 40 km as observed by SAGE instruments. However, the total impact of increased CO2 and other greenhouse gases on the middle atmosphere has still to be investigated properly.

The Solar Backscattered Ultraviolet Radiometers (SBUV/2) are currently operating on the NOAA-9 and NOAA-11 meteorological satellites. A major validation effort on the NOAA-9 observations is currently underway by an ad hoc joint NOAA-NASA science team. Available for evaluation is a 3 1/2 - year data set soon to be extended to more than four years. Comparisons of the SBUV/2 data are being made with similar data from ground-based Dobson observations and from other satellite instruments, namely SAGE II and the SBUV/TOMS system on Nimbus-7. A major NASA experiment in the Fall of 1989 will be a Shuttle mission carrying an SBUV instrument. Data from all systems are to be used in assembling the most valid and useable ozone data set.

6. Geology and Productivity of Land Surfaces and Oceans

a. Geological Studies

Remote sensing and other space technologies continue to be developed and employed as a valuable tool in geological studies. In the German Democratic Republic an Intercosmos Remote Sensing Experiment was conducted in Tenshan in August of 1988, and the accumulated data are under analysis for geological and technical research. In the United States a Geological Remote Sensing Field Experiment (GRSFE) was conducted during the summer of 1989 in the Mojave Desert of the Western United States to perform experiments that would guide the development of improved space-borne observing facilities for the late 1990's. One of the key planning meetings that occurred was one defining Solid Earth Science research using NASA technologies. This meeting was held in the state of Maryland in the United States in the late summer. The principal thrusts designated for the 1990's included soils research, implementation of a topographic mapping mission, emphasis on potential fields research, and volcanic activity, and climate interactions. It was proposed that Fiducial Laboratories for an International National Science Network (FLINN) consisting of over 200 permanent stations be implemented for geodynamics observations. This network would utilize existing Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) stations. Plans are also proceeding to formulate a joint U.S./NASA and ESA potential fields mission called "Arisoteles" and well as a joint U.S./NASA and France/CNES mission called "Magnolia" to study the secular variation of the Earth's main magnetic field for studies of core/mantle interactions, etc. The second United Nations International Training Course on "Remote Sensing Applications to Geological Sciences" has been organized for Potsdam during October 5-22, 1989, within the U.N. Space Applications Programme.

In Czechoslovakia the major geological (and ecological) efforts have been accomplished in the context of the Intercosmos Program working group for the Remote Sensing of the Earth. The Priroda (nature) project has seen the conduct of geological projects in the Tienshan and Luzice Mountain areas of the USSR polygon and in the Czechoslovakia/Poland/GDR frontier region.

b. Land Productivity Studies

During the past year the International Satellite Land Surface Climatology Project (ISLSCP) activities continued. There was a follow-up to the First ISLSCP Field Experiment (FIFE) that occurred in the Konza Prairie region of the United States. Besides involving many of the original FIFE investigators, several Soviet scientists visited the FIFE site as part of a bi-lateral agreement that includes the potential for doing ISLSCP studies or exchanging relevant results from the Soviet Union. In addition a workshop on results from the HAPEX-Mobilhy Experiment was held in October, 1988, to review recent results from that experiment. Planning meetings have been held concerning ISLSCP experiments that will take place in Spain in 1991 and 1994, Niger in 1992 and in Canada or the U.S. in 1992. In the U. S./Canada discussions the focus is on a follow-up experiment to the FIFE work with emphasis on boreal forest processes. The efforts in Spain and in Niger would have experiment designs that more resemble the HAPEX-Mobilhy experiment performed in France in 1986.

The United States has been involved in a technology transfer activity designed to incorporate the use of vegetation index data in the food security programs of four Association of South East Asian Nations (ASEAN) member countries. A four-week workshop on the topic of Satellite Crop Monitoring was conducted at the Asian Institute of Technology in Bangkok in June-July, 1989. Follow up country missions and a Regional Evaluation Seminar are being held to assure effective transfer of data and techniques and to determine the level of interest in expansion of the program. The activity involves the qualitative interpretation of vegetation conditions and trends from composited vegetation index imagery and the quantitative use of time-series Normalized Difference Vegetation Index (NDVI) data for agro-climatic regions of interest within the countries. The goal of the project is improved information for operational Agro-Climatic Assessment Bulletins prepared in the participating countries leading to more effective early warning and food security programs.

As part of the World Climate Research Programme (WCRP) plans continue to go forward for the Global Energy and Water Experiment (GEWEX). This effort will have a strong hydrological component in it including coupled hydrological-atmospheric models and the study of land surface processes employing the approaches or being performed in conjunction with the HAPEX-Mobilhy and FIFE experiments mentioned above. The next meeting of the GEWEX Scientific Steering Group will be in Paris in January of 1990.

There are many other studies using remote sensing that are continuing in several countries. In South Africa, for example, drought and pasture studies are being performed using the vegetation index approach employing AVHRR data. Catchment land cover change studies and the mapping of inpondments and irrigated areas are being accomplished using satellite data. A conference on Geosphere-Biosphere Change, responding to the International Geosphere Biosphere Program (IGBP) will be held in Cape Town, South Africa in December, 1989. Work is continuing successfully to use active and passive microwave remote sensing to estimate snow and ice properties. Notable applications of the Nimbus Scanning Multichannel Microwave Radiometer (SMMR) and the U.S. Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSMI) are being developed for snow and ice studies in Switzerland, England, and the United States. In Hungary several agrometeorological projects are continuing using METEOR 1939 MSU-E and Landsat MSS and TM data.

c. Ocean Productivity Studies

Work continues in the U.S., Canada, the Federal Republic of Germany, and other countries to use ocean color observations from aircraft and spacecraft to study ocean color observations as they relate to the productivity of the oceans. Observations of fluorescence are being successfully employed for this purpose using airborne scanner data in Canada, for example. The Nimbus Coastal Zone Color Scanner (CZCS) data are being processed for several years and yielding global ocean color observations that indicate considerable temporal and spatial detail that is new and revealing about the extent of photosynthetic activity in the oceans of the world. Plans are proceeding in the United States for a follow-up satellite capability to observe ocean color called SeaWIFS or perhaps Proteus. This capability would employ an advanced multi-channel ocean color sensor much improved over the CZCS.

The MOS-1 Japanese instruments appear to also be offering interesting ocean observations related to ocean productivity. In Japan in the middle of the year 1989 a five-year programme on "Understanding Global Phenomena by Satellite Observations" began with a special sub-programme on air-sea processes as observed from space.

d. Advanced Technology Efforts

In the U.S. a large effort is underway to implement for the Earth Observing System (EOS) for the late 1990's. In Canada the Canadian Space Agency (CSA) was established. Landsat, Spot, and NOAA satellite data are being routinely received in Canada, and the Japanese MOS-1 data are being received experimentally. Efforts in Canada are refining the concept of the RADARSAT for operation in the 1990's. In the Federal Republic of Germany a C-band Synthetic Aperture Radar (SAR) and an X-band SAR have been successfully developed for airborne application that also lend preparatory information for the ERS-1 mission.

The C-band SAR was used for several campaigns for agriculture, snow and ice research in the Alps, ocean research, and calibration experiments. An X-band SAR for Space Shuttle applications is being implemented for missions in the 1991-1994 time frame. In the FRG imaging radiometers for oil pollution, agriculture, and forestry applications have been built for frequencies up to 140 GHz.

7. International Programmes

a. International Satellite Cloud Climatology Project (ISCCP)

The ISCCP has been approved by the Joint Scientific Committee to continue until at least mid 1993. Processing of global operational satellite observations has provided data sets covering at least two years. ISCCP results showing spatial distributions of cloud parameters are distributed to various research organizations for further detailed analyses and validation studies.

The well calibrated ISCCP radiance data sets are now subjects of analyses to determine Surface Radiation Budget parameters. While this is relatively easy for global radiation and surface albedos, additional means are necessary to determine the downward atmospheric radiation.

b. Global Precipitation Climatology Project (GPCP)

The operational images of geostationary satellites are still subjects of analyses with respect to the probability of tropical rainfall. Results are then merged with similar information determined from images and sounding data from polar orbiting satellites. The WCRP has established a global data center at the Deutscher Wetterdienst at Offenbach. Several meetings of the working group on data management have been held during this period.

c. The International Satellite Land Surface Climatology Project (ISLSCP)

Many research groups of several countries continued to measure heat transfer over well defined continental surfaces for the purpose of deriving algorithms which could be applied to satellite data. In a joint Chinese-Japanese programme, the HEIFE, (Heihe River Field Experiment) such algorithms will be tested over semi-arid areas.

d. International Geosphere-Biosphere Programme (IGBP)

The international preparations for IGBP continued. This programme is set up to observe and understand changes in our environment on Earth. The goals of this multi-year efforts are to describe and understand the basic physical, chemical, and biological processes on Earth. IGBP however requires a solid data base. Therefore a new experiment, Global Energy and Water Cycle Experiment (GEWEX) has been established during the last couple of years. Its purpose is to provide a platform for thorough determinations of data on the energy transfer within the climate system and on the entire water cycle. Particular attention will be paid to this experiment on the development of further software to analyze already existing satellite data. Furthermore new instruments need to be developed to measure, in particular, the evaporation over the Earth's oceans.

CHAPTER II

SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM

1. The Terrestrial Planets

a. Venus

The processing and analysing of the data from the radar survey of Venus by the Soviet Venera 15 and 16 spacecraft were continued. Four 1:15,000,000 scale maps of the area surveyed, including photomosaics, shaded relief, topography, and geology have been published by the US Geological Survey as a joint US/USSR project. An "Atlas of Venus" containing a comprehensive set of Venus maps and images is to be published in the USSR at the end of 1989. These publications will provide the international scientific community with access to the data.

The analysis of Venera 15/16 data made by scientists of the USSR, US, GDR, FRG, and Finland provides the planning and interpretational guidelines for the NASA Magellan mission. Magellan was successfully launched to Venus on 4 May 1989. It will arrive at the planet on 10 August 1990 and will start mapping the surface of Venus with its powerful radar system.

b. Mars

The red planet was studied by the Soviet Phobos-2 spacecraft using instrumentation developed as a result of broad international collaboration. A large number of observations was successfully carried out at high elliptic and circular equatorial orbits. Gamma-spectroscopic measurements at 4 pericenter approaches to the planet confirm the essentially mafic composition of the surface material. IR-mapping radiometry enabled CO2-absorption altimetry of the near-equatorial areas. It also found prominent variations in an H2O absorption band that were interpreted as strong differences in H2O content in the solid material of the surface. UV and IR scanning radiometry provided data on the surface temperature. Data on the plasma environment around the planet were also obtained; these give some confirmation of the existence of an intrinsic Martian magnetic field.

c. Phobos

This natural satellite of Mars was to be studied by the USSR Phobos spacecraft with very close flybys (50 meters above the surface). Unfortunately, communication with the spacecraft was prematurely lost on 27 March 1989 during the gradual approach to Phobos. However, some new data on this asteroid-like body was delivered to Earth prior to the loss of communication. The TV imaging provided a number of pictures of the position and shape of Phobos' surface, albedo variations, and morphology for the areas poorly imaged by previous missions. UV radiometry and IR mapping spectrometry indicate possible compositional variations over the surface. A new estimation of the mass of Phobos has been obtained from the spacecraft orbit tracking ($1.08\pm0.01 \times 10^{19}$g), yielding a density of 1.98g/cm3.

2. The Outer Planets

a. Jupiter

As this report is being written (mid-September), plans for the launch of the Galileo spacecraft are still firm for 12 October 1989. The new trajectory for Galileo will take it past Venus, the Earth/Moon and an asteroid before it reaches Jupiter in 1995. Some scientific observations are planned for each of these encounters.

b. Saturn

The Cassini Mission was approved by both NASA and ESA for a new start in October 1989. This mission will consist of a NASA Saturn orbiter carrying an ESA probe that will be deployed into Titan's atmosphere. ESA has approved its participation in this mission as of mid-September; approval of the mission by the U.S. is expected. Launch is scheduled for April 1996.

c. Neptune

The Voyager 2 spacecraft completed a successful flyby of Neptune in late August. Only some of the highlights of this encounter can be given here.

Six new satellites were discovered. They comprise a regular system well inside the orbit of Triton. Two narrow discrete rings were found instead of the expected arcs. A third more diffuse ring and a wide faint ring extending from inside the outer discrete ring toward the planet were found as well.

The general circulation of Neptune's atmosphere was found to resemble that of Uranus; the highest wind velocities are to be found near the poles. Given the difference in the two planets' obliquities this was surprising. On the other hand, only Neptune exhibits a large oval dark spot reminiscent of Jupiter's Great Red Spot in addition to discrete white clouds resembling those seen in the Uranus atmosphere.

The magnetic field of Neptune also shows similarities to that of Uranus in that it is dipolar and inclined approximately 50 degrees to the rotational axis. The maximum field strength is 1.2 Gauss.

An excellent series of images of Triton revealed that this satellite has undergone a complicated history. Impact craters are certainly present, although there are not as many per unit area as would correspond to an unmodified ancient surface. Frost features abound, which suggests that many of the absorption bands identified in ground-based spectra in fact correspond to solid rather than gaseous methane and nitrogen. The mean surface temperature is less than 40 K, making Triton's the coldest sunlit surface in the solar system. The surface pressure of the nitrogen-dominated atmosphere is only a few microbars. Yet there are dark streaks of material at several places on the surface which suggest wind-blown debris.

The wealth of data returned by Voyager 2 promises to yield many new insights into the Neptune system during the months ahead. The analysis is being carried out by teams composed of scientists from around the world.

3. Small Bodies in the Solar System

a. Comets

Comet Halley data acquired on the Vega and Giotto missions has continued to provide scope for in-depth analysis. In particular, the HMC Giotto camera imaging data has been enhanced and composite image sequences now resolve morphological features on the nucleus; photometric analysis of the images allows the accurate definition of the anisotropy of the dust emission pattern, which can be compared with the Vega data, but the nucleus rotation status remains an unresolved question. Analysis of larger particle impact data on Giotto and other data now confirm the significance of large particles (in the mass range 1 gram) undetected by remote optical techniques. Halley data now demonstrate a highly anisotropic dust-rich nucleus with a well insulated crust; active but small emission regions on the sunward face generate the dust emission. The presence of significant dust fluxes in non-solar directions is demonstrated Elemental analysis of microparticles in impacts on Vega and Giotto spacecraft has provided further data relating them to very primitive chondritic material and to their pre-solar nature; particulate densities have also been determined ranging from those of loose agglomerates (below 1 gram/cm3) to mineral grains (several grams/cm3).

Approval of the campaign for the checkout of Giotto has been reached within ESA and with NASA. This enables ESA and NASA to cooperate to establish the spacecraft status after its Halley encounter and hibernation. Subject to technical viability and funding a further encounter with comet Grigg-Skjellerup is anticipated in July 1992 following Earth swing-by in July 1990.

A joint study team supported by ESA and NASA has continued study of the Comet Nucleus Sample Return mission (CNSR-Rosetta). Contributing to the mission concept development and the interpretation of space data, the FRG comet simulation facility KOSI has been established to provide opportunity to study the physics of subliming dust-ice mixes.

NASA's Comet Rendezvous and Asteroid Fly-by mission (CRAF) will rendezvous with Comet Kopff on 31st December 2000 following launch on 22 August 1995. Instruments have been selected for the mission. NASA's Mariner Mark II mission combines the CRAF and the Cassini missions.

b. Asteroids

Encounter of a mainbelt asteroid by the NASA-FRG space mission Galileo is anticipated to take place in 1994 enroute to Jupiter. The future Cassini and CRAF missions are also scheduled for asteroid flybys, which should contribute to a better understanding of the closer relationship being established between comets and asteroids in the context of the pre-solar nebula.

c. Analysis of Extraterrestrial Material

Retrieval of NASA's Long Duration Exposure Facility (LDEF) in December 1989 returns to Earth data on the space environment which may exceed today's accumulated knowledge. Relevant to the study of minor bodies, particulate impact experiments are used to define accurately both natural meteoroids and artificial space debris over the 5 year period 1984-1989. Particulate capture cell configurations offer unprecedented opportunities for the chemical and isotopic analysis of residues of high significance to the origin of the space dust.

In NASA's space station program experiments have been selected for the Attached Payload providing a Cosmic Dust Collection Facility (CDCF). The facility will provide for laboratory analysis of the returned samples, which are combined with accurate measurements of the orbital elements of captured matter. USSR exposure of surfaces on the Mir station has already returned extraterrestrial samples for analysis. Within ESA studies on an advanced facility DUSTWATCH have confirmed their results in the context of space particulates. ESA's microgravity platform, Eureca, is scheduled for launch by NASA's Space Shuttle in May 1991. It will deploy a time resolved microparticle capture cell system.

4. Space Techniques for Geodesy and Geodynamics

Space tracking techniques aim primarily at monitoring the Earth rotation and crustal motions, control of the terrestrial reference frame, and mapping the long wavelength structure of the gravity field. The techniques involved are Global Positioning System (GPS), Laser Tracking, and Very Long Baseline Interferometry.

a. Very Long Baseline Interferometry (VLBI)

There exists a global VLBI network of 20 fixed stations and 3 mobile stations which have been intensively operated across the Atlantic, across the Pacific, and in the Western US for crustal deformation and Earth rotation studies. The latter activity provides Earth orientation information of the highest quality on a regular basis and publishes monthly reports.

NASA and the US Geodetic Survey have been operating two mobile VLBI systems in Alaska and Canada. A third mobile system performed baseline measurements at a number of points in Western Europe.

The VLBI network in the United States will be augmented considerably by the part-time availability of the VLBI array (VLBA) consisting of 10 stations with 25 dishes. The first test measurements at one of these sites, namely Pie Town, New Mexico, were performed in 1989. A VLBI station network, called QUASAR, which consists of six stations, is presently under development in the USSR.

Other fixed VLBI stations that will soon be operational, at least part time, to support geodetic measurements are the stations in Matera and Noto in Italy and the FRG and Japanese stations in Esperanza and Syowa, respectively, in the Antarctic. Institutions in China, Brazil, Saudi Arabia, and India are planning additional VLBI activities.

b. Satellite Laser Tracking Activities

In 1988/89 SLR tracking data to the primary three satellite targets Lageos, Starlette, and Ajisai were reported from 36 sites in 20 different countries. These data are primarily used for terrestrial reference frame and Earth rotation investigations as well as for global to regional crustal motion and long wavelength Earth gravity field studies.

In 1988 the NASA and German mobile laser ranging systems performed measurements in North America and the Pacific region. In 1989 there was the first repetition of the Mediterranean Laser Campaign (MEDLAS) with a reoccupation of sites in Turkey and Greece by a US, a Dutch, and a German mobile facility.

A Japanese mobile laser ranging system has been used at various sites in Japan. New laser data have been reported from the Simeiz station (USSR). A few new stations have delivered engineering data: Kiev (USSR), Kavalur (India), Riad (Saudi Arabia), Plana (Bulgaria).

c. Global Positioning System Activities

The global positioning system (GPS) aims at the practice of geodesy and geodynamics. A cooperative GPS network called CIGNET is at present continuously tracking the GPS satellites to provide a fiducial data set that may be used for orbit computation and research. The currently participating stations are located in Europe (Wettzell, Tromso, Onsala), the USA (Richmond, Westford, Mojave, Yelloknife), and Japan (Tsukuba). The data from all stations are sent weekly to the National Geodetic Survey in Rockville, USA, where they are archived, reformatted, and compiled. On request these global data are available to everybody. Many regional to local GPS projects were carried out in the 1988/89 period, e.g.:

- the CASA UNO geodynamics project, organized by JPL and covering the Caribbean - South American region
- various GPS campaigns in the Mediterranean area as cooperative programs of Italian/FRG, Greek/English/FRG/US, Turkish/FRG/US groups
- crustal motion study programs along the Sumatra fault system (Indonesia/USA/Japan), in Papua/New Guinea (Australia), and in Japan

d. New Satellites

During the reporting period the USSR launched three satellites specifically for geodetic/geodynamic purposes. These are the GEO-IK satellite launched in May 1988 and the Etalon 1 and 2 satellites launched in January and May 1989, respectively.

GEO-IK is a medium altitude spacecraft (1500km) at 74 degrees inclination equipped with laser retroreflectors, a doppler transmitter, and flashing lights for geodetic positioning purposes. ETALON 1 and 2 are put into a near circular orbit at 64.8 degrees inclination and a semimajor axis of 25,500km. These satellites are of the cannon-ball type and only equipped with laser retroreflectors.

The first Block II GPS satellite was launched by the United States in February 1989. The Soviet Union continued to launch satellites of the GLONASS navigation system.

CHAPTER III

SPACE STUDIES OF THE ATMOSPHERES OF THE EARTH AND PLANETS, INCLUDING REFERENCE ATMOSPHERES

1. The Earth's Middle Atmosphere

At the end of 1989 a very fruitful research period, the Middle Atmosphere Program (MAP), and its follow-up period MAC will be terminated. In the last two years results from in situ observations were sparse. The research activities in this field were concentrated on ground-based observations using various new techniques for instance lidars, radars, and optical instruments such as interferometers. A series of data from these techniques was collected under CEDAR, a program which is focussed on the coupling of different atmospheric and ionospheric regions.

The field which attracts the scientific community particularly today is the study of long-term variation of temperature and transport. Relationships between these variations and the solar activity or the equatorial QBO (Quasi Biennial Oscillations) were positive in many different places up to the mesopause level at northern latitudes. A physical explanation of this effect discovered by Labitzke and van Loon has not been found yet.

The international efforts to study the ozone depletion over Antarctica have revealed the importance of chemical and photochemical reactions in the presence of aerosols. The potential hazards for the ozone loss from such reactions in the presence of sulfuric acid aerosols at mid-latitudes is obvious but not yet recognized by the scientific community.

The future of the research in the middle atmosphere and lower ionosphere is coordinated in the Solar Terrestrial Energy Program (STEP). In the period 1990-1992 the emphasis will be on satellite experiments on UARS and on planned campaigns such as Dyana, Crest, and Decimals/NLC 91 using ground-based and in situ measurements.

2. The Earth's Upper Atmosphere and Ionosphere

During the two-year period under review the national and international space research efforts carried out within the areas of the thermosphere and ionosphere have been limited by the relatively small number of dedicated rocket or satellite launches which have occurred.

During the past two years the single major spacecraft dedicated to research in this field which has been launched was the San Marcos satellite (Italy/NASA - March 1988). This spacecraft is expected to continue in operation for the immediate future. It provides observational data on electric fields, the neutral upper atmosphere, and the ionosphere, as well as energetic particle precipitation and solar ionizing fluxes. Individual instruments have, however, also been flown on a number of other spacecraft with primary objectives in other areas, particularly in the USA and USSR space programmes.

Particular examples are the Space Environment Monitors on the USA NOAA/TIROS spacecraft, which define and routinely monitor the energetic particle fluxes incident on the upper atmosphere, and the USA DMSP spacecraft which carry instruments to measure ion drifts/electric fields, energetic particles, and magnetic fields. The data from previous instruments in these satellite series have made a major contribution to climatology studies of the upper atmosphere and ionosphere through their empirical models of magnetospheric inputs. With the current and projected future coverage it will be possible to use the observations for near real-time meteorological studies and numerical modelling of the upper atmosphere and ionosphere.

The global electric circuit is largely driven by the external magnetospheric convective field at high latitudes and by the global E-region dynamo with an internal source, mainly thunderstorm-generated fields in the lower atmosphere. Investigations of the global electric circuit have been re-activated as a result of the discovery of occasional but unexpectedly large middle atmosphere

electric fields. The recent discovery of significant correlations between both long-term and short-term solar variability and climatological variability and the possible link between these variations and the QBO, has also been a factor in coupling changes between regions of the atmosphere which are somewhat decoupled by direct interchange processes (diffusion, momentum exchanges).

A considerable amount of progress in thermospheric and ionospheric studies is now coming from ground based optical and radar measurements. This empirical work is strongly supported by major research programmes using sophisticated numerical models of the coupled atmosphere-ionosphere regions. Further valuable information on the magnetospheric inputs of energy and momentum comes from monitors in meteorological programme spacecraft in low earth orbits. These measure energetic processes, auroral emissions, electric fields/ion drifts and field-aligned currents. Unfortunately, none of the plans of the major space agencies include significant resources for appropriate direct and remote sensing observations of the thermosphere and ionosphere, using a coordinated package of synergetic instruments, prior to the ESA/NASA polar platforms in the late 1990s. Some valuable measurements of the lower thermosphere will be made in the 1991-1993 period, from NASA's Upper atmosphere Research Satellite (UARS).

A large number of sounding rocket experiments involving chemical releases (CRIT II and CRRES) and injection experiments (ARCS and Spear) are planned either alone or around expected satellite missions. Several satellite experiments will be devoted to wave injections (APEX) or releases (CRRES-GOT, CRRES-LEO-LL, Active). Several ground based experiments using ionospheric heaters are planned at high and low latitudes (Arecibo and Tromso).

3. Planetary Atmospheres and Aeronomy

The two recent years have provided the community with disappointments, successes, and hopes for the future. Of the two Phobos spacecraft, one failed en route to Mars. The other reached the planet and provided some valuable information before it, too, was lost. On the other hand, the Voyager encounter with Neptune was a spectacular success. Quite recently the Galileo mission to Jupiter was successfully put into orbit by the space shuttle.

As far as future missions are concerned NASA and ESA have approved the Cassini/Huygens probes to study the Saturn system, and ESA has plans for an extended Giotto mission to the comet Grigg-Skjellerup.

4. The Venus International Reference Atmosphere (VIRA)

Information is being compiled to update VIRA. The most recent information is included in the book entitled "The Venus Atmosphere" (Keating, G.M., Editor, Advances in Space Research, Vol. 10 No. 5 1990). This publication is the proceedings of the July 1988 COSPAR Workshop "The Middle and Upper Atmosphere of Venus" which was held in Espoo, Finland. The principal purpose of the meeting was to present the latest results concerning the Venus atmosphere obtained from U.S. and Soviet spacecraft for possible incorporation in VIRA and to identify the major remaining unknowns concerning the atmosphere to give focus for future measurements and studies.

Important new results included the following. From Pioneer Venus data large long-term solar cycle changes have been detected in the Venus ionosphere and in the altitude of the bow shock. The Vega balloons give evidence of a much more active middle atmosphere than previously suspected. Unexpectedly strong and variable vertical winds (1-3 m/sec) were detected by both Vega balloons. Vega-2 detected substantial northward winds which pushed the balloon nearly 500 km toward the equator during its 2-day flight. The temperature structure of the middle atmosphere has been derived independent of the earlier Pioneer Venus Orbiter Infrared Radiometer (VOIR) data by means of the Venera-15 Fourier spectrometer data. The new results confirm in general the earlier results summarized in VIRA. From the Venera-15 Fourier spectrometer data water vapor and sulfur dioxide abundances were also determined and were found to be consistent with 70-85% sulfuric acid concentration in aerosol droplets at the Venus cloud tops.

5. Reference Atmospheres

The compilation of the new COSPAR International Reference Atmosphere (CIRA) is nearly completed. The new CIRA follows reference atmospheres adopted by COSPAR in 1961, 1965, and 1972. The new CIRA will be divided into two volumes: Volume 1 - the thermosphere and Volume 2 - the middle atmosphere. Work has been completed in assembling the sections of Volume 1 including a semi-empirical thermosphere model and new theoretical and numerical models. The text, tables, and figures of Volume 1 have been published in Vol. 6 Nos. 5-6 of Advances in Space Research under the title "CIRA: 1986 Part I Thermosphere Models (Rees, D. Editor). The middle atmosphere volume of CIRA will include satellite data whereas the previous version used in situ and ground based measurements. The two hemispheres will be treated separately, and values will be provided at closer spacing than before. Mean longitudinal variations in the form of the amplitude and phase of planetary waves 1 and 2 will be included for the stratosphere and mesosphere. For the first time, systematic variations of zonal means ozone are included covering ozone as a function of latitude and season in both the stratosphere and mesosphere using combined data from 6 satellite experiments.

The COSPAR Sub-Commission C.4 on CIRA has also organized a major activity of developing proposed reference models of minor species in the middle atmosphere and lower thermosphere including models of 0_3, N_20, HNO_3, N_20, CH4, CO_2, CFC's, 0, NO, and aerosols. In accord with a recent proposal of the MAP Steering Committee of SCOSTEP, it is planned that these models of minor species will be published in 1989 as a MAP Handbook for distribution to and feedback from the international scientific community prior to publication as a CIRA document. The models may be used as a common means of comparison of measurements, as a common reference model for comparison to theoretical studies, and as common input where measurements are dependent on "first guess".

6. URSI/COSPAR Task Group on the International Reference Ionosphere (IRI)

The publication of the IRI-90 Handbook of IRI by the National Space Science Data Center and World Data Center A for rockets and satellites is planned for spring 1990. It will synthesize the most important advances achieved during the recent years.

It will be called "International Reference Ionosphere 1990" and will be the result of a wide international collaboration.

Having in mind the terms of reference of IRI, six chapters are planned. They will be related to: the general IRI project, an ion drift model, a model of the ion composition, a model of the cluster and negative ions repartition; the plasma temperatures anisotropies, and the study of the relations of IRI with the electron content measurements.

The revised computer code will also be described. It will make use of all the experience gained recently. Many of these recent advances were presented and discussed at the two last Workshop of IRI: the first, held in 1988 in Espoo during the Plenary Meeting of COSPAR and the second in August 1989 in Abingdon (UK). The scientific contributions of both Workshops will appear in Advances in Space Research.

At the Abingdon Workshop, future study programs have been planned. They will be based mainly on the intensive use of topside sounders and of the main ionospheric vertical soundings networks, on comparisons with incoherent scatter data, and on special rocket experiments together with modeling efforts. An improved collaboration with URSI Working Group G4 is expected.

As has always been the case, the activity of IRI is the result of a very active and broad international cooperation.

CHAPTER IV

SPACE PLASMAS IN THE SOLAR SYSTEM

In COSPAR, Commission D is responsible for the study of space plasma physics. The most tenuous parts of the solar system are in the plasma state: the upper levels of the Earth's atmosphere, the outer corona of the Sun, the solar wind, the ionised atmosphere of each of the planets, the magnetospheres of Jupiter and Saturn, and the extended plasma environments of comets. The bulk of our firm knowledge of the physics of plasmas in space comes from measurements made in-situ by space probes.

Substantial additional information has come from balloons, rocket probes, and ground based facilities such as radars. All the planets of the solar system as far out as Neptune have now been visited by spacecraft. As space vehicles like Pioneers 10/11 and Voyagers 1/2 probe further from the Sun we await the first indication of the heliopause, the boundary of the heliosphere, marking the limit of the Sun's direct influence in space.

There were two very important events in the year, the culmination of the Phobos mission and the Voyager encounter with the Neptune system. The year has also seen the launch of the Japanese "Akebono" (EXOS D) spacecraft.

In the first three months of the year the Soviet Phobos 2 spacecraft orbited the planet Mars. Sadly the probe failed some 200 km short of its prime target, the moon Phobos, an object of great interest because of its suspected origin as a captured asteroid. The spacecraft were well equipped with magnetometers, plasma wave detectors, and charged particle detectors to study the martian plasma environment as well as the solar wind during the cruise phase to Mars. Surprisingly, the most critical question, whether the solar wind-Mars interaction is magnetospheric or ionospheric in nature, is as yet unresolved.

During the initial Phobos orbits of Mars it approached within 850 km of the planet. Just prior to closest approach the spacecraft entered a plasma regime which appeared to contain only ions of planetary origin. However it seems as likely as not that the spacecraft at this time entered an induced magnetosphere rather than one created by an internal planetary field. The later circular orbits which cross the magnetotail at about 6000 km distance detect a field whose orientation depends on the upstream solar wind field direction rather than indicating any planetary related component.

The Phobos mission marks the start of a Soviet programme of Mars exploration up to the end of the century. The next major mission is planned for launch in 1994. Known as MARS 94, the programme will include balloons, penetrators, and remote stations on the planetary surface. Amongst the proposed payload for the orbiter spacecraft is a package of field and plasma instrumentation to measure the plasma environment of the planet. Once again, as in the Vega and Phobos missions, instrumentation from a large number of nations will be carried.

The second important event has been the final Voyager mission encounter with a planet; in late August the Voyager 2 spacecraft, launched in 1977, flew past Neptune and its massive moon Triton before heading off towards interstellar space. At time of writing information is short on the details of the plasma environment of Neptune, but it is clear that the Neptunian magnetosphere is different from all other planetary magnetospheres. The planetary dipole is very substantially offset from the planetary rotation axis and also the dipole axis is very strongly tilted from the rotation axis. The Voyager spacecraft seems to have entered almost along the polar cusp of the planet. There seems little energetic radiation belt population. In the next year, there will no doubt be much analysis of the intriguing geometry and its consequence for the plasma environment.

The plans for the major international ISTP (International Solar-Terrestrial Physics) programme have gone forward this year and the first space craft, the Japanese Akebono spacecraft, has been launched. New images of the Earth's aurora have been obtained along with a variety of other measurements of auroral related phenomena. The Soviet Activny spacecraft is to be launched in September, and coordinated study using Akebono, Activny, and the US Dynamics Explorer spacecraft is planned early in the new year.

Planning continues for the ESA/NASA STSP space programme. It is made up of two separate missions known as SOHO and Cluster designed to give a coordinated programme in solar and solar terrestrial physics. Plans are also progressing for the coordination of the Cluster mission with a series of Soviet spacecraft known as Regata using a novel attitude control system based on solar radiation pressure.

During the nineties space agencies in the United States and Japan, ESA in Western Europe and Intercosmos in Eastern Europe are putting together a large multi-spacecraft programme to investigate plasma processes in the near Earth space in the next decade. Construction of the major Japanese contribution, GEOTAIL, is well under way. This spacecraft will explore the magnetotail of the Earth whilst NASA spacecraft monitor conditions upstream of the system in the solar wind and in the ring current region of the inner magnetosphere, and the distant polar magnetosphere. A Soviet spacecraft, the first of the Regata series, will cover the near Earth tail. This phase will be followed by the ESA-led Cluster mission, wherein four spacecraft will fly in close formation to study field and plasma microstructure in the magnetosphere, in coordination with a parallel Soviet spacecraft programme.

The space plasma interest focuses on one of the two component STSP missions, Cluster. Cluster is a four spacecraft mission designed to study in detail processes like magnetic reconnection, hydromagnetic waves and turbulence which occur in other solar, planetary, and astrophysical contexts. These can be studied in situ in a manner impossible in other situations. The boundary regions between the magnetospheric and solar wind plasmas are the site of a variety of anomalous plasma phenomena which are not well understood,and doubtless fundamental physics will result from the first use of multipoint measurements in the high altitude magnetosphere.

Soviet scientists are leading an Intercosmos multispacecraft programme, Interball, which is also directed at the study of magnetospheric plasma processes. In some respects a development of the recent Dynamics Explorer and Viking projects, the programme will feature pairs of spacecraft in low and high orbit respectively with the aim of further studying the interrelationship of ionospheric and magnetospheric processes.

No spacecraft has yet reached the edge of the solar influence in the interstellar medium, a hypothetical boundary known as the heliopause (at the edge of the heliosphere) although Pioneer spacecraft and now the two Voyager spacecraft are heading out away from the solar system. Planning for a major future study of the inner heliosphere awaits the launch of the ESA/NASA Ulysses spacecraft which is now fixed for autumn 1990. The mission will be the first to explore significantly out of the ecliptic plane. The spacecraft is to fly initially to Jupiter where a gravity-assist manoeuvre would send it out of the ecliptic plane to explore the polar distant solar environment, the heliosphere. Until Ulysses is launched our direct knowledge of the extended solar environment, the solar wind, is restricted to the ecliptic plane. Ulysses will introduce the third dimension, which is at present only studiable by rather indirect means such as by examining interplanetary radio scintillations.

The Galileo Jupiter orbiter and probe mission is currently on the launch pad at Cape Canaveral ready for launch in mid-October. The mission is substantially complicated by the decision not to use the Centaur booster. In 1990 the spacecraft will flyby Venus before returning to Earth for gravity-assist manoeuvres before setting off for the jovian system by way of the asteroid belt. The orbiter is to perform the first detailed programme of studies of the jovian magnetosphere including a pass deep into the magnetotail region and planned flights through potential or actual plasma wakes of various of the jovian moons. The many entirely surprising features of the jovian magnetosphere revealed by the two Voyager encounters leave much important science hanging on Galileo's eventual arrival in orbit.

New missions awaiting the final stages of approval this year include Cassini-Huygens, a Saturn Orbiter/Titan Probe to be done jointly by NASA and ESA, and CRAF (Cometary Rendezvous Asteroid Flyby).

The field of active experiments in space, that part of space science which actually uses injections of gases, plasmas or radio waves to probe ambient conditions, has been hit by the shuttle delays. The CRRES (Combined Release and Radiation Effects Satellite) mission, the USA, is to be launched next year using an expendable launch vehicle.

It thus follows that the area of research is active with exciting programmes to come. Finally, it is important to note that, although the core research in space plasma science must be through in situ measurements from space platforms, there are worldwide ancillary programmes of ground based observations of various kinds with telescopes, radars, magnetometer chains, riometers, etc. Furthermore, unique measurements are made by means of balloon-borne instrumentation and instruments carried on sub-orbital rocket flights.

CHAPTER V

RESEARCH IN ASTROPHYSICS FROM SPACE

1. Galactic and Extragalactic Astronomy 1988-89

This year the International Ultraviolet Explorer satellite, a joint effort of ESA, NASA, and the SRC, continued to perform well as described below; the Ginga X-ray satellite of Japan continued X-ray observations; and resumption of NASA's space transportation system after the Challenger disaster has lead and will lead to the launch of a number of missions in galactic and extragalactic astronomy. Space agencies around the world are planning a full range of scientifically rewarding missions which are discussed below in order of increasing energy of radiations.

Several major aims are embodied in the programs for NASA and ESA. NASA envisions four Great Observatories working together to produce astrophysical observations over more than a dozen orders of magnitude in spectral range. All of the observatories would be of a size requiring shuttle launch, and NASA envisions revisits for such functions as servicing, refurbishment, or reboost. All are intended for long service lives and, by standards of size, flexibility, and longevity, would have the status of observatory-class facilities. They would make use of the US national space infrastructure depending as they do, in varying degrees on the flexibility implicit in shuttle support, OMV (Orbital Maneuvering Vehicle) retrieval and deployment, Space Station servicing, TDRSS (Tracking and Data Relay Satellite System) communications and the NSSDC (National Space Science Data Center) and Science Data Archives. Three of the four of NASA's Great Observatories, HST, GRO and AXAF have been given U.S. Congressional approval and HST is considered to be among the highest of NASA's priorities. SIRTF will be the last Observatory to fly.

ESA has defined a program of moderate missions and cornerstone missions as a part of its long term Horizon 2000 program for space science and is actively moving ahead with plans to develop and launch the components of this program. The four cornerstones of the program are: the solar terrestrial program (SOHO/Cluster); a mission to primordial bodies including return of pristine material; a high efficiency X-Ray mission for Spectroscopic studies between 0.1-20 keV (XMM); a high efficiency Heterodyne Spectroscopy Mission (FIRST). It is the last two named missions, XMM and FIRST that concern this report on Astronomy. Moderate missions also contained in the Horizon 2000 program, Hipparcos, HST participation, and ISO, are discussed below.

The USSR has maintained a program of scientific research in space during this reporting period, and anticipates an active set of instruments both as free flyers and also carried on the space station Mir. Emphasis is centered on X-Ray astronomy. The national programs of Japan, the FRG, and Italy are included below under the appropriate energy regime.

Infrared, Submillimeter, and Radio Spectral Regions

COBE, the Cosmic Background Explorer, is a NASA Delta-class Explorer mission that will produce maps of the sky in 100 wavelength intervals over a spectral range extending from 1 micron to 1 cm. COBE will look for spatial anisotropies in the cosmic background radiation to a sensitivity of a few times 10E4 K. Interplanetary and interstellar dust, primeval and infrared galaxies, and the stellar background can be discriminated by their spectra and mapped. COBE will be launched on a Delta-class rocket in November, 1989.

The next purely ESA astronomical instrument is the Infrared Space Observatory ISO, which is a follow-up to IRAS. Its cryogenically cooled telescope will be equipped with four scientific instruments which together will permit imaging, photometric, spectroscopic, and polarimetric measurements at wavelengths 2.3 to 200 microns. ISO, which is scheduled for launch in 1993, has a planned mission lifetime of at least 18 months. It will be operated as an observatory with two thirds of the observing time available to the general astronomical community.

NASA is proposing to replace the Kuiper Airborne Observatory, the KAO, with SOFIA, the Stratospheric Observatory for Infrared Astronomy. The KAO is a one meter telescope carried to altitudes above 12 kilometers by a modified C-141 cargo jet. SOFIA is a proposed joint project of the U.S. and the FRG consisting of a 2.7-meter infrared telescope carried by a modified Boeing 747SP aircraft. The Federal Republic of Germany would provide the telescope, bearings, and pointing system while the U.S. would provide the modified aircraft. SOFIA would have approximately 10 times the sensitivity of the KAO and provide a flexible observing tool and test platform for decades to come.

The Space Infra-Red Telescope Facility (SIRTF) would be the last in the series of NASA's Great Observatories Program. This cryogenically-cooled telescope will exceed the sensitivity of IRAS by three orders of magnitude. There will be three instruments on board: a spectrometer, a direct imaging camera, and a precision photometer, the latter capable of operation over a very broad range of wavelengths. SIRTF has a planned life of at least 5 years and will occupy a 100,000 km circular orbit. Currently a new start in 1993 is anticipated.

A "Scout-class" Explorer program was opened by NASA in an effort to provide a mechanism by which experiments could gain access to a fast-track (3 years) from laboratory to orbit. The program should enable approximately yearly launches of limited-scope missions. The first astronomy selection in this program is a submillimeter spectroscopic survey instrument.

Preparatory work is underway on ESA's cornerstone mission for submillimeter astronomy (FIRST). The science Advisory Groups have defined baseline concepts which will be the object of an extensive industrial system definition study to be started in October, 1989. Several design concepts will be examined, for example a mission based on an 8m diameter antenna, a smaller mission with a 4m antenna, and a number of options including use of mechanical coolers, heterodyne receivers, and incoherent detectors. The study will be completed by the end of 1990 or in early 1991.

Very long baseline interferometry at radio frequencies is of interest to many nations because the achievable baselines and hence spatial resolution can be increased dramatically when antennas in Earth orbit can be operated in conjunction with Earth-based arrays. The USSR is planning the Radioastron mission - an antenna in space - by the mid-1990s. International participation includes ground-tracking support by NASA. Another VLBI experiment, involving a space-based antenna, VSOP, is being planned by Japan's ISAS. This project would also involve the United States and Australia.

Italian scientists will explore the infrared wavelength region with two balloon-borne telescopes: TIR, a 3-meter millimetric mirror, and TRIP, a 25-cm near-infrared telescope. One of the main scientific goals is the study of the diffuse cosmic background, its anisotropies, and its smoothness, all features of paramount cosmological relevance. There is also a commitment for Italian scientists to provide the ESA satellite ISO with two of its four detectors, the LWS and the ISOCAM camera.

Optical and Ultraviolet Spectral Regions

IUE has continued to operate into its 11th year with no degradation in scientific performance. The project, a collaboration between ESA, NASA, and the SRC of the UK, performs UV spectroscopy in the 1152 to 3200 Angstrom wavelength region. IUE will leave a legacy which will stand for decades. The IUE legacy derives both from the experiment's scientific contributions and

also from its success as a model international mission. IUE has shown that facility-class missions which rely heavily on centralized data archiving and those that rely on the Guest Observer as opposed to Principal Investigator mode of operation can be uniquely productive. The satellite has been used by 1500 astronomers over its lifetime and has contributed over 1400 papers to refered journals. The archives of IUE are becoming an increasingly popular tool for research. A lesson has been learned from this circumstance and many future missions will archive data together with essential engineering background information. Archival research may grow to be a major mode of astronomical research for future space missions.

IUE also is a model for international sharing of observing opportunities in space astronomy. IUE has shown that European and U.S. scientists can time-share a spacecraft in a manner characterized by high scientific productivity and by a synergistic scientific interaction. IUE is also a model for scientific cooperation on a broader scale. Scientists from all over the world have obtained observations with IUE. Demand for observing time remains high. The long life of the mission benefits studies of long-term variability and provides increased scope for coordinated observations with ground-based and space-borne observatories such as Exosat, Ginga, and, in the future, ROSAT. Operations are hoped to continue into the 1990s. A wide range of topics have been studied among which significant observing time was devoted to studying SN1987A which yielded information on some 200 spectral lines as well as the signature of a UV light echo.

ESA's Hipparcos mission is dedicated to the precise positional measurement of some 100,000 selected stars brighter than B=13 magnitude. Target accuracies of 2 milliarcseconds are achievable by the observational technique which employs a satellite in a geostationary orbit. The two fields of the telescope, which are offset 58 degrees from each other, slowly turn around the satellite spin axis. The spin axis moves such that it precesses around the Sun 6.4 times per year. This scanning pattern ensures that the position of a particular star relative to many other stars about 58 degrees away is measured a large number of times. Hipparcos was launched on 8 August, 1989. As it was not possible to inject it into the planned geostationary orbit, the spacecraft remained in a geostationary transfer orbit from which it could still operate, although with an anticipated reduction in lifetime. Under these conditions a portion of the original scientific objectives could still be achieved. Preliminary evaluations suggest that an astrometric catalogue of 100,000 stars could be completed with a precision at least equal to that of the best available catalogues, which refer to far fewer stars (ca. 1000). As an example, an abbreviated mission of 4 to 6 months duration would still result in a state-of-the-art position for most of the stars in the Hipparcos Input Catalogue but would not provide parallaxes and proper motions. The Tycho experiment would also be expected to provide accurate positions and two-color photometry for some 400,000 stars, albeit with a somewhat reduced accuracy with respect to the original mission goal. However, a deeper analysis and a more precise estimate of the lifetime of the spacecraft in the present conditions are necessary before decisions are taken concerning the future of the Hipparcos project.

NASA's Hubble Space Telescope (HST) will be the first of the Great Observatories program when it is launched in the first quarter of 1990. HST is a 2.4-meter aperture diffraction-limited "optical" telescope having instruments permitting observations over a spectral range extending from 1150 Angstroms to 1.1 micron with a subsequent upgrade extending IR performance to 2.5 microns. The six initial instruments are: the FOC (Faint Object Camera) provided by ESA, WF/PC (Wide Field/Planetary Camera), FOS (Faint Object Spectrograph), GHRS (Goddard High Resolution Spectrograph), HSP (High Speed Photometer) and FGS (Fine Guidance System, used in astrometry). During a future revisit/reboost an infrared (2.5 micron) instrument (NICMOS) and a versatile imager/high-resolution spectrograph (STIS) will replace two of the current instruments. ESA is also contributing to the HST project the FOC mentioned above, the solar arrays, and scientific and technical support to the ST Science Institute at Baltimore, USA. European astronomers from ESA member states are guaranteed a minimum of 15% of the observing time on HST. These observations are to be supported through the ESA/ESO European Coordinating Facility situated at Garching, FRG. Requests for observing time on HST exceed the available time by a factor of six.

ASTRO-1: ASTRO/BBXRT experiments will fly in NASA's shuttle bay as part of the Spacelab program. One part of the mission consists of three co-pointed far ultraviolet telescopes, HUT, UIT, and WUPPE, respectively, spectroscopic, imaging, and polarimetric instruments operating at wavelengths as short as 900 Angstroms. The X-Ray telescope BBXRT is discussed below. ASTRO-1 is scheduled to fly in the spring of 1990.

EUVE, the Extreme Ultraviolet Explorer in NASA's Delta-class Explorer program, will produce an all-sky survey in 4 broad spectral bands extending from the region shortward of the Lyman cutoff at 912 Angstroms down to about 100 Angstroms. Prior to 1975 and to the Apollo-Soyuz mission, it was thought that absorption at these wavelengths would be too great for detection of extra-Solar-System sources. We now know of at least 20 sources, but no sensitive survey has yet been performed. Following the preliminary survey of EUVE a second deeper survey, 100 times more sensitive, will be carried out along a 1 degree wide great circle on the sky and will be followed by detailed spectroscopy on individual newly-discovered sources. EUVE will be launched in the second half of 1991.

ORFEUS is a joint experiment of the FRG Space Agency BMFT and the US's NASA. ORFEUS will consist of a German one-meter-class telescope capable of operating in the ultraviolet between 500 and 1200 Angstroms. The telescope will be deployed from NASA's shuttle cargo bay during the course of an 11-day mission aboard the German ASTROSPAS carrier and will carry three spectroscopic instrument packages. The spectrographs will be provided by the University of Tuebingen, the University of California/Berkeley, and Princeton University. Launch is anticipated in 1992.

In late 1989 NASA selected two additional Explorer missions for Phase B study in its Delta-class program: ACE, the Advanced Composition Explorer, for examination of composition of accelerated nuclei in the energy range 1 keV to 100 MeV and LYMAN/FUSE for high resolution spectroscopy in the 900 to 1200 Angstrom region with extension to approximately 100 Angstrom.

X-Rays, Gamma-Rays, and Cosmic Rays

The post operational phase of ESA's Exosat is approaching its conclusion. The X-ray Astronomy Satellite Exosat operated from May, 1983 until April, 1986, having completed 1780 observations covering a wide range of astronomical objects. Efforts since the end of operations have concentrated on the preparation of a data archive, which has been in great demand with the scientific community. The data-base, which is publicly available, contains a summary of results from each observation as well as products (images, light curves, and spectra) which are accessible to a remote user. The user may also request transfer of the final product, which reduces the need to transfer "raw data".

The USSR's Space Agency IKI has operated the QVANT module attached to the Mir space station. This module includes principally X-Ray spectroscopic experiments to measure galactic and extragalactic sources. The supernova in the Large Magellanic Cloud, SN 1987A, was an object well studied by these instruments.

Japan's Space Agency, ISAS, continued to operate the successful Ginga mission throughout the year, and scientists around the world collaborated in the interpretation of X-ray measurements made by the satellite.

NASA's Gamma-Ray Observatory (GRO), a component of NASA's Great Observatories Program, includes four instruments: EGRET; OSSE; COMPTEL; and BATSE. EGRET, the Energetic Gamma-Ray Experiment Telescope, is a spark chamber instrument providing mapping, timing, and spectral information in the 50 MeV to 10 GeV range. OSSE, the Oriented Scintillation Spectrometer Experiment, carries out broad-band spectroscopy in the 50 keV to 10 MeV region, providing observations, for example, of the supernova tracer Aluminum 26. COMPTEL, the Compton Telescope, uses Compton scattering and two sets of scintillators to produce low-background maps at energies in the 1 to 30 MeV range. BATSE, the Burst and Transient Source Experiment, uses crystal detectors to search for gamma-ray bursts and locates these to within approximately a degree. Hundreds of such detections are expected over the life of the experiment. GRO is scheduled for launch in the summer of 1990.

IKI is planning an X-Ray satellite mission, Spectrum X-Gamma, that will be built and launched into high elliptical orbit by the USSR. Spectrum X-Gamma will carry payload components provided by international participants including an X-Ray spectrometer provided by Denmark, an X-Ray polarimeter provided by Italy, and an X-Ray polarimeter and X-Ray all-sky monitor supplied by the United States. Current plans call for launch in the mid-1990s.
The Advanced X-Ray Astrophysics Facility (AXAF) is a part of NASA's Great Observatories program. The main optical system for AXAF consists of a set of 6 nested Wolter type I grazing incidence mirrors having an overall aperture of 1.2 meter and is designed to work in the energy range 0.1 to 10 keV. Three of four instruments now under development will be chosen for flight. The four focal-plane instruments being developed include two imagers (one microchannel-plate and one CCD based) and two spectrometers (one crystal-dispersive type and one cryogenically-cooled calorimeter type). High resolution spectroscopy will be performed using transmission gratings in conjunction with the imaging detectors. AXAF will be launched in the mid-1990s.

XTE, the X-Ray Timing Explorer, is a part of NASA's Delta-class Explorer program. Three experiments comprise XTE: a large area proportional counter array operating in the 0.5 to 60 keV range, scintillation detectors for high energy X-ray timing in the 20 to 200 keV range, and an all-sky monitor which surveys approximately 80% of the sky every 30 minutes. The planned lifetime of the mission is 2 years. Launch is planned for the mid-1990s.

ASTRO-1: ASTRO/BBXRT is a part of NASA's Space Shuttle based scientific research program. In addition to the ultraviolet components described above, there will be an X-Ray telescope. Adjacent to the ultraviolet instruments, on a separate pointer, is the Broad Band X-Ray Telescope, BBXRT, designed for spectroscopy in the 0.3 to 10 keV range. The first ASTRO mission will be launched in 1989; the reflight for the second mission is planned for 1991.

ROSAT is a joint experiment of the FRG and the U.S. ROSAT will perform soft x-ray imaging using a German nested Wolter mirror telescope producing arcsecond resolution over the energy range 0.1 to 2.0 keV. After the U.S. launch, German scientists will use the telescope to produce the first all-sky survey in this energy range during the initial half year of telescope operation. After the survey has been completed, a joint U.S.-German program of Guest Observer pointed observations will begin. It will use the German imaging proportional counter and a U.S. microchannel plate imager. Launch is scheduled for 1990.

ASTRO-D. This is a joint mission of the Japanese space agency, ISAS and the U.S. NASA. The experiment will use a U.S.-built concentrator similar to that employed in BBXRT together with focal-plane instrumentation to perform high efficiency imaging spectroscopy in the 1 - 10 keV range. The U.S. will provide one of the focal plane instruments in addition to the concentrator. Launch is expected in 1993.

The second ESA cornerstone Mission (after SOHO/Cluster) is XMM, the High Through-put X-Ray Astronomy Mission, for which focal-plane instruments were selected in 1989. The telescope uses nested grazing-incidence X-ray mirrors covering the energy range 0.1 keV to 20 keV. With a planned launch in the mid-1990s, the first and important step of technological demonstration of its mirror-fabricating techniques is well advanced, and the first replicated mirror shells have already been evaluated in the 'Panter' X-ray calibration facility. The performance of these shells is extremely promising. It is intended to operate XMM as an observatory having a satellite design lifetime of two years and a target lifetime of ten years.

There are two national projects being carried out by Italy: the X-Ray satellite SAX which should operate in the energy band 0.1-200 keV and a balloon program in X-and Gamma-ray astronomy. The SAX satellite is still in the developing stage. Characteristics of the instruments to be flown have been decided and the specifications distributed to the institutions that proposed them. Some prototypes have been developed and flown on balloons. There are several balloon projects: PALLAS, LAPEX, and POKER in the X-Ray domain; GAMTEL-ZEBRA, FIGARO, and LIME

in the Gamma-Ray energy region. Flights from Brazil (POKER) and Australia (LAPEX) have provided data on hard X-Rays from SN 1987A. ZEBRA, an Italian-British collaboration, was flown from Palestine, Texas in the summer of 1989. Some of these experiments are equipped for the study of both galactic and extragalactic steady sources as well as for variable sources and the detection of Gamma-Ray bursts. Active Galactic Nuclei (AGNs) are currently observed with Ginga in collaboration with Japanese colleagues. Instruments for future missions besides SAX are under construction by Italian scientists: an X-Ray spectrometer for the JET-X telescope, an X-Ray polarimeter for the USSR Spectrum X-Gamma, and also some of the detectors for XMM. Italian participation can also be found in COMPTEL, which is to be flown on NASA's GRO.

2. Solar Physics

Introduction

The scientific study of the Sun has expanded greatly in the space age. We study the Sun as an interesting object in its own right and also because of its interest for astrophysics as a whole (the "solar-stellar connection" probably best exemplified by studies of phenomena related to magnetic activity on the Sun and stars) and - perhaps even most importantly - because of its direct effects on the Earth and mankind, through the influence of solar variability over timescales ranging from minutes to centuries ("solar-terrestrial physics"). The former application of solar physics emphasizes its astronomical heritage in that the tools of remote sensing, with ever increasing capabilities in the telescopes that are used, predominate. In the latter application there is also an appeal to in situ measurements of the outer solar atmosphere - the heliosphere - with emphasis on the terrestrial consequences of heliospheric disturbances.

Solar physics is thus a truly interdisciplinary and unique field. No other branch of astronomical research encompasses so many techniques and has at the same time such profound bearing on the future of our civilization. As humankind extends it frontiers into space with permanently inhabited space stations and the future colonization of other bodies of the solar system, the accurate knowledge of physical processes on the Sun - responsible for "space weather and climate" will vastly exceed current needs. Furthermore, the Sun is used as a Rosetta Stone to understand many aspects of stellar evolution, structure, and activity.

Solar Activity

In the past three decades the greatest flowering of solar physics from space has come in the domain of high-energy phenomena such as EUV, UV, X-ray and gamma-ray photon emission, charged-particle and neutron emission from the Sun. The study of visible light emission, as in the case of space-borne coronagraphs, has also contributed greatly to our understanding of yet another type of phenomenon - the magnetic field emission - of profound implications for the structuring and transient phenomena in the interplanetary medium and the magnetospheres of the Earth and other planets. We now regard the combined understanding of high energy phenomena such as particle acceleration and heating as revealed by energetic photon emission together with the dynamics of the magnetic field as the key to understanding solar flares and other transient activity.

Quiet Sun

The study of the "quiescent" solar atmosphere has also flourished via UV observations in particular. The key problems in this area are associated with the coupling of the cool photosphere into the hot corona and its extension to the solar wind. Results from space-borne instruments such as those flown on Spacelab as well as other missions and rocket flights have shown - with the invaluable help of ground based data - the paramount importance of magnetic fields in shaping up the highly turbulent "face" of the Sun. In addition to well known phenomena associated with the subsurface convective layers - such as the solar granulation - we now see that

the solar atmosphere is permeated by magnetic fields of different distributions, intensities, and lifetimes which are in continuous evolution. Most atmospheric structures from features at the limit of present-day telescopes (a few hundred kilometers on the solar surface) to the large-scale unipolar regions called coronal holes, owe their existence to the complex interaction between the plasma and the magnetic field. The existence of the high temperature corona above active regions is clearly linked to the dissipation of energy in closed field regions - loops - while open field regions in coronal holes are the site where the solar wind is accelerated in a way not completely understood as yet. Abundant new data have given clear indication that field emergence, submergence, and reconnection are core physical processes that drive atmospheric phenomena at all spatial and temporal scales.

Solar Interior

The techniques of space research are also being brought to bear on the understanding of the structure and dynamics of the solar interior and convection zone. The new field of "helioseismology" had its first dedicated space-borne instrument for the study of global oscillations aboard the Phobos (U.S.S.R.) spacecraft. High resolution observations under the perfect "seeing" conditions of space observatories and the continuous monitoring allowed by these in many cases are ideal for probing the solar subsurface structure by means of the study of oscillatory modes at many frequencies and spatial scales. These observations will help in the resolution of the question posed by the enigmatic low solar neutrino flux and will also help in our understanding of energy transport in the solar interior, astrophysical convection, and the generation of solar and stellar magnetic fields.

Future Missions and Programs - Solar Activity

With the solar cycle reaching its 22nd maximum, the study of solar flares and other active phenomena is one of the major driving forces in the planning of future mission operations. This new maximum which promises to be one of the largest in modern history will not be monitored by a major solar observatory like the Solar Maximum Mission (SMM) spacecraft launched in 1980. While no equivalent solar satellite will observe this maximum, the SMM - repaired in orbit by Shuttle astronauts in 1984 - is expected to lose attitude control and subsequently re-enter the Earth atmosphere by the end of 1989. This surprisingly early re-entry is, ironically, due to the large and earlier-than-expected increase in solar activity during the current cycle.

Solar A

The SOLAR A mission, which is to be launched by Japan in 1991, will carry a complement of instruments to monitor energetic flare phenomena and the evolution of coronal magnetic structures. This will be the sole spacecraft totally devoted to solar observations during the upcoming maximum. Its payload includes a high resolution soft X-ray telescope provided by the USA and a Bragg crystal spectrometer developed jointly by UK and USA experimenters. The Japanese instruments include an advanced Fourier-synthesis hard X-ray telescope, which will have considerably improved sensitivity, energy range, and spatial resolution over imaging detectors previously flown aboard the SMM (U.S.) and the Hinotori (Japan) spacecraft. Higher energy hard X-rays, gamma-rays, and neutrons will also be monitored by SOLAR A instruments. Significant improvements in temporal resolution, e.g. 2 seconds in gamma-ray spectra as compared to the 16 seconds of the SMM spectrometer, should provide new insights into the understanding of particle acceleration and interaction processes in flares.

Ulysses

Ulysses, formerly known as the International Solar Polar Mission, will carry two small scintillation detectors to observe X-rays from 15 to 150 keV. A unique characteristic of this mission is that it will provide solar observations from outside the ecliptic plane. It will use Jupiter's gravitational field to direct the spacecraft on a trajectory which will pass over the north pole of the Sun. Therefore Ulysses, in combination with other spacecraft, will provide the capability for stereoscopic views of hard X-ray emitting sources on the Sun. Detectors similar to those of Ulysses were also flown on the Phobos missions. The unfortunate early demise of these two spacecraft, which also carried imaging X-ray and visible light instruments, has prevented joint observing programs even before the launch of Ulysses.

Sigma

SIGMA is a French experiment aboard a Soviet GRANAT satellite. Although its main objective is to map the gamma-ray sky and locate non-solar sources (pointing limitations prevent SIGMA from directly viewing the Sun) its cosmic gamma-ray burst detectors can also obtain flare spectra up to energies of 100 MeV. Additional solar capabilities of SIGMA include high sensitivity and temporal resolution observation of flare emission within the 50 keV to 7.5 MeV range.

Wind

The WIND spacecraft, a component of the Global Geospace System (GGS), which is part of the International Solar-Terrestrial Program (ISTP), will carry a high-purity germanium detector to obtain measurements of solar flares and cosmic gamma-ray bursts in the 25 keV to 8 MeV energy range. In addition to gathering information of gamma-ray lines due to accelerated particles in large events, the spectrometer will provide nearly continuous monitoring of hard X-ray emission from flares with spectral resolution superior to that of the SMM spacecraft.

GRO

The Gamma-Ray Observatory (GRO) is NASA's next major mission in high-energy astrophysics. GRO, which is scheduled for launch in 1990, will carry four large instruments with the objective of obtaining comprehensive observations of cosmic sources in the 20 keV to 30 GeV energy range. In addition to its primary goal, GRO will also provide very significant capabilities for the observation of solar radiation - gamma-ray and accelerated neutrons - which are evidence of the most energetic processes occurring in flares. Of the four instruments, the Burst and Transient Source Experiment (BATSE) will have great capabilities for flare observations due to its large sensitive area. It should provide extensive high temporal resolution observations of flare emission in the 50 to 1000 keV energy range. Observations of the nuclear line regior of the spectrum will be provided by two other instruments, the Oriented Scintillation Spectrometer Experiment (OSSE) and the Imaging Compton (COMPTEL), while the Energetic Gamma-Ray Experiment and Telescope (EGRET) (which covers the 20 MeV to 30 GeV portion of the spectrum) will probe the most energetic phenomena on the Sun.

Balloon Programs

Several countries, including the People's Republic of China and the USA in particular, have plans to carry out balloon observations with dedicated flare physics oriented instruments. Many of these will be carried out in long-duration balloon flights. In the case of the USA, NASA-sponsored part of the solar maximum - Max 91 - program includes the development and flight of three state-of-the-art instruments. The Gamma-Ray Imaging Device (GRID), based on Fourier-transform techniques to obtain high spatial resolution images, will observe solar radiation in the 20 keV to 1 MeV range. The High Resolution Gamma-Ray and Hard X-Ray Spectrometer (HIREGS) will be able to investigate through high spectral resolution (15 keV - 20 MeV) the various non-thermal and thermal processes in flares. The Solar Optical Universal Polarimeter (SOUP) will provide new insights into the physical processes of magnetic energy storage in active regions.

The International Flares 22 Project

In an international effort, tailored after the highly successful Solar Maximum Year (SMY) program of the early 80's, the worldwide solar community will join forces once again on a program of flare research at the maximum of cycle 22 - FLARES 22. An integral part of the Solar-Terrestrial Energy Program (STEP), sponsored by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), FLARES 22 will be a novel experience in this type of activity. As noted in our introduction, the only dedicated solar space mission scheduled to be flown during the upcoming maximum will be Solar A. Research on active phenomena will therefore require the analysis of data from many individual spacecraft and balloon experiments as well as highly improved ground-based observatories. The FLARES 22 project will thus be a vehicle to coordinate worldwide observations of solar activity. Concurrently and subsequently, it will focus international attention and collaboration upon the analyses of these data and upon the theoretical work they inspire.

Future Mission and Programs - Quiet Sun

Major research areas of current interest in quiet Sun studies are helioseismology, atmospheric fine structure, coronal heating and the origin of the solar wind. In spite of lack of new data, partially imposed by delays due the Challenger accident, quiet Sun studies still proceed at a good pace during the present report period. The data obtained by the Soviet Phobos missions are still being analyzed at this time, while those from Spacelab 2 are still providing new results on dynamic and structural aspects of the quiet solar atmosphere.

Many new results on solar granulation (convective overshoot and turbulent flows), oscillatory motions, internal gravity waves and magnetic fields come from the analysis of data from the Solar Optical Universal Polarimeter aboard Spacelab 2. As already noted, SOUP is one of those instruments selected to be flown in NASA's Max '91 balloon program. Therefore, in addition to its specific solar activity purposes, SOUP will also provide new data pertaining to quiet Sun studies to complement longer term ground-based observations.

Similarly, and in order to avoid repetition, we note here that many spacecraft listed under the Solar Activity section of this report have excellent quiet Sun capabilities. For example, the soft X-ray telescope aboard SOLAR-A will provide the first quasi-continuous set of synoptic X-ray pictures of the Sun since Skylab - more than a decade and a half ago! Moreover, since Skylab operated during a period of relative calm, the SOLAR-A full Sun pictures will be the first ever obtained at solar maximum. Other spacecraft that will contribute to our knowledge about the quiet Sun and the heliosphere are Ulysses and WIND.

SOHO

The European Space Agency's Solar and Heliospheric Observatory (SOHO) is scheduled to be launched in 1995. It will orbit at the Sun-Earth Lagrangian point at 1.5 million kilometers from our planet, a location that offers continuous viewing of the Sun and an ideal site for in situ measurements of solar wind phenomena. In many ways SOHO is the most ambitious project in solar research ever planned. Its instruments will probe the entire solar structure from its interior (through helioseismology measurements) to the outermost layers of the solar corona and the heliosphere. This large endeavor is a common venture of many European countries and the USA with participation of scientists from all over the world. Its magnitude can be easily perceived from the mere listing of the instruments that have been selected to fly.

The helioseismology instruments include GOLF (Global Oscillations at Low Frequencies), VIRGO (Variability of Solar Irradiance) and MDI/SOI (Michelson Doppler Imager). These will measure global oscillations, the solar radiative output, and magnetic fields. A detailed view of the solar atmosphere from the chromosphere to the corona is the scope of SUMER (Solar Ultraviolet Coronagraph Spectrometer) and LASCO (white light and spectrometric coronagraph). All combined, these instruments can measure temperature, density, and velocity of solar plasma at various layers, the evolution of atmospheric structures and the transport of mass, momentum, and energy up to a height of 30 solar radii. Last but not least, SWAN (Solar Wind Anisotropies), CELIAS (Charge Element and Isotope Analysis), COSTER (Comprehensive Suprathermal and Energetic Particle Analyzer), and ERNE (Energetic and Relativistic Nuclei and Electron Experiment) will probe many aspects of the solar wind. These instruments, as shown by their names, will measure physical parameters and anistropies in the wind, its higher energy components and then relate them back to coronal structures and dynamic phenomena.

OSL and ASO

The Orbiting Solar Laboratory (OSL) and the Advanced Solar Observatory (ASO), belong to a different category than those missions described up to now - they are projects based on obvious needs to continue the advance of solar research in the next century. The OSL is the restructured program to fly a one meter optical telescope for high spatial - photospheric photon mean free

path - resolution solar studies. The ASO is a proposed quasi-permanent space observatory dedicated to the study of the fundamental problems in solar physics. OSL would be the optical component of the ASO, which also includes a Solar High-Energy Facility.

These projects, among others, belong to the bright future of solar physics at the start of the next millenium.

CHAPTER VI

LIFE SCIENCES AND SPACE RESEARCH

1. Results of Space Flight Experiments in the Field of Life Sciences

Manned Space Flight

In the reporting period the longest missions with humans took place: the Soviet cosmonauts Titov and Manarov spent 366 days in the orbital station MIR. Apart from the operational significance of this mission, the data gathered on the human body's reaction and the countermeasures applied to prevent the body's complete adaptation to weightlessness have added much to the understanding of human physiology as such. Probably the most surprising element of this endurance flight is that the cosmonauts returned to Earth in extremely good health and readapted to Earth's gravity rapidly. This could be interpreted as to both the physiological pathways and regulatory mechanisms have been understood, and the countermeasures were - after several modifications over the past years - correctly applied. For the first time, a medical doctor spent some 8 months on board, partially overlapping with the 1 year long term crew and the following crew. Intensive professional medical know-how was therefore added to this mission and may have contributed to the successful completion of these studies.

Moreover, since the U.S. Space Shuttle resumed its flight in October 1988, the emphasis on manned missions and its associated research in human physiology has gained momentum in the western world. In particular, in preparing the Space Station scenario, the U.S. are mounting an effort with studies on the human body's reaction to 16-20 days mission in weightlessness termed 'Long Duration Orbiter' (LDO). Both Shuttle middeck and Spacelab experiments will be involved, and the first Life Sciences dedicated mission by NASA (SLS-1) is already "visible on the horizon" for a June 1990 launch.

Basic Biology

The Soviet launched Biocosmos (Cosmos 1887) which contained primates, rodents, plants, tissues, bacteria, etc., yielded a wealth of information on living systems' reaction to both weightlessness and cosmic radiation. The experimental data were presented in Moscow about one year after landing, at the end of November 1988. This mission, which was probably larger than any previously mounted, saw the largest international cooperation, including Western European countries and the United States: some 200 scientists participated, many of whom actively supported the research on this mission. In the meantime, another Biocosmos satellite, no. 9 in this series, was successfully launched in September 1989, and retrieved almost 14 days later.The payload was similar in its composition to that of its predecessor, and, likewise, the experimental results will be up for review in about 1 years time. Not surprisingly as in most research areas of biology, experiments have to be repeated, both for statistical purposes and reproducibility of result.

Planning and Future Activities

The planning of "free flyer", unmanned satellites, retrievable from low earth orbits, have also attracted, the interest of the life sciences community. These research platforms, e.g. "Lifesat" in the U.S., "Raumkurier" in the FRG, have the advantage of being comparatively cheap and more easily accessible with a higher launch rate if compared to manned systems. The Soviet Biokosmos missions are typical in this context.

With the resumption of the U.S. Shuttle flights, the Spacelab missions have gained a serious momentum: SLS-1 and SLS-2, IML-1, and 2, D-2, and future M-missions (Multinational) will soon become reality and work up the backlog of some hundreds of experiments already selected in the life sciences, ESA, for example, develops a multi-user facility termed "ANTHRORACK"

(from Greek anthropos = man) supporting human body systems analysis in an integral fashion based on non-invasive techniques. Earth-based models for quick "check-ups" or detailed diagnosis e.g. in the cardiovascular, pulmonary or metabolic systems at the same time, are in planning. For the longer term future, planning for outfitting the U.S. Space Station Freedom with multiuser laboratories (e.g. BIOLAB, ANTHROLAB, Variable G-centrifuge are well underway: plans are also mounted in the USSR to add a "Medilab" to Mir, a large Module completely equipped for biomedical research.

2. Radiation Biology

Radiation biology as related to space research is concerned with two major topics, the objectives of which are closely interrelated, of course. The first approach simply views the rather unique radiation environment in space together with the other distinctive factors of spaceflight, such as weightlessness, as an otherwise inaccessible tool to study the responses of biological systems affected by these factors either separately or in combination. The second approach involves assessing the extent to which the well-being of man might be affected and what protective measures might be needed to combat the assault of these factors.

Ground Research

For both approaches a combination of terrestrial investigations and direct experimentation in space remains the cornerstone of scientific progress. These terrestrial investigations continued worldwide, especially with heavy ions, at the major particle accelerators such as in Berkeley (USA), in Dubna (USSR), or in Darmstadt (FRG). For the GSI accelerator in Darmstadt the upgrade to higher particle energies was completed so that now the energies for a realistic simulation of the heavy ion space environment are available.

Spaceflight Experiments

The major activities occurred in the Soviet space programme, where the final analysis of experiments on the Biocosmos (Cosmos 1887) mission was completed. In addition to an overall agreement with previous results on the interaction between heavy ion radiation effects and weightlessness, some intriguing discrepancies were discovered which remain to be resolved. Preparations continue for radiobiological experiments in the forthcoming space missions such as the U.S. IML mission, the Soviet BIOCOSMOS missions 9 and 10, and the German D2 mission. Apart from biological investigations, the accumulation of dosimetric data for the near earth space environment continues as a necessary task.

Radiation Protection

The deliberations of the Scientific Committee 75 of the National Council on Radiation Protection and Measurements (NCRP) of the United States finally appeared in print as NCRP report No. 98, "Guidance on Radiation Received in Space Activities", after six years of preparation. In Europe the European Space Agency ESA is establishing a standing advisory committee to guide their manned space activities regarding the requirements of radiation protection.

3. Planetary Biology and Origins of Life

Significant progress has been made in the following areas:

Interstellar Medium

Photochemical reactions on interstellar grains are viewed as important sources for the production of interstellar organic molecules. Crucial questions under discussion are: Did chiral organic molecules already arise in interstellar space? To what degree did the organic molecules of the presolar cloud on the early Earth survive? Can a simulation of gas-grain interactions be realized in a gas-grain simulation facility on a space platform within the next 10 years?

Comets

The interest still focusses on Halley's organic molecules. Interstellar dust is considered to be the source of organic molecules in Halley. So far the organic matter in the nucleus of comets cannot be analyzed directly. Sample return missions to comets are under discussion. So far the composition of the cometary core can only be deduced from the data on the dust and the gases emitted by comet Halley (PUMA 1; Vega 1).

Other Small Bodies of the Solar System

Evidence for macromolecular compounds has been obtained by evaluation of the dark surfaces of asteroids and comets. The analysis of organic compounds in carbonaceous chondrites (including micrometeorites collected in Antarctica) have brought more insights into their genesis: The materials probably have evolved from interstellar molecules, but they were subsequently changed by radiation chemical processes (as in comets) and additional hydrothermal processes.

Chemical Evolution on the Outer Planets

Interest has focussed on organic compounds in the atmosphere of Titan, a satellite of Saturn, and of the giant planets Jupiter and Saturn. The simulation experiments serve primarily as preparatory studies for the planning of later exploratory missions to these bodies.

Chemical Evolution on Early Earth and Mars

It is now largely agreed that on Earth and Mars about 4 billion years ago related processes of chemical evolution took place. Both planets had a CO_2/N_2 atmosphere. Such an atmosphere is only a very poor source for the production of bioorganic molecules by interaction with electric discharges, UV light, ionizing radiation, shock waves, volcanic heat and the like. It is therefore assumed that the early carbospheres of these planets originated to a large degree from impacts of comets and carbonaceous chondrites (meteorites). HCN and formaldehyde appear to be major constituents of cometary nuclei. Experimental work has focussed on the conversion of these compounds into other materials by experiments simulating assumed prebiotic reactions in the laboratory.

Biochemical Evolution on Early Earth

The research has focussed on the following issues:

- Were the first enzymes nucleic acids?
- Can nucleic acids replicate themselves and synthesize peptide bonds without the help of proteins?
- How and when did chiralic systems (optical activity) originate?
- How did early bioenergetic pathways evolve?
- What is the source of genetic information?

No direct answers are available to these questions. The difficulties are immense because life probably evolved in a chaotic sequence of events that cannot be reproduced. An additional difficulty is that a prebiotic route to replicable nucleic acids has not yet been detected and that nucleic acids in presently living organisms are only synthesized with the help of proteins (as enzymes and cofactors).

Life in Extreme Environments

Research has focussed on the questions:

- Has life existed on early Mars?
- Is there still life on Mars in some ecological niches?
- Could some terrestrial life forms survive and replicate in such niches on Mars?

There is abundant evidence indicating that liquid water existed on early Mars. The surface of contemporary Mars is generally too cold and the atmospheric pressure (a CO_2/N_2 atmosphere) too low to allow for the existence of a liquid water phase. But astonishing observations of growth of microorganism in frozen lakes and rocks (endolithic systems) in Antarctica support the view that life might be possible in some niches on Mars. This view is also supported by the evidence that on Earth many species of microorganism exist that grow in the absence of molecular oxygen, even in the dark (e.g. methanogenic bacteria).

Planetary Protection

Sample return missions from comet nucleus (CNSR) and the Mars surface (MRSR) are currently under study in the US, USSR, and Europe (ESA). A joint policy under the guidance of COSPAR to avoid contamination of target bodies by terrestrial microbes and back contamination of Earth by extraterrestrial microbes has been advanced.

4. **Natural and Artificial Ecosystems**

Biospherics

a. Remote Sensing Technology

Recent work in remote sensing technology has been largely concerned with the problems of signal distortion from passage through the atmosphere and by the physical interaction of light with canopy surfaces and with leaf architecture. This has primarily involved modeling from theory and from limited experimental data. Models describing signal attenuation in the atmosphere are reasonably well developed, and await experiments that provide adequate characterization of the atmosphere, along with spectral measurements. Most existing models are very sensitive to moisture. The concept of "standard atmospheres" for modeling marine, urban, and rural landscapes is gaining strength. At the canopy level, research has been directed to the effects of leaf architecture on signal attenuation. Leaf models are currently poor relative to whole canopy models because leaf structures' effect on light is poorly understood. Difficulties with intra-leaf spectral measurements have thus far limited this work. Typical leaf surfaces and internal structures are patchy and uneven. Vascular tissues may act as light pipes; surface characteristics such as hairs or waxy cuticle may be reflective or scattering. While the photosynthetic chloroplasts occur near the cell surface, photosynthetically-active cells may be clustered within the leaf ("C4" photosynthetic architecture). Programs for studying these characteristics in the laboratory are now in progress. During this period two workshops were sponsored by NASA to outline problems and experimental approaches in these areas.

Both to support theoretical work and to provide data for verification of models, experimental work is underway to quantify leaf biochemicals and examine correlations of biochemical content with visible and near infrared spectra using several statistical methods. New methods to isolate these materials with altering their structures appear promising. Recent reports on spectral analysis suggest that leaf tissue spectra can be decomposed into component spectra. This work is directed at replacing the empirical methods of determining biochemical content from spectra with a fundamental understanding of the chemistry producing the spectra. Of increasing interest are biological problems at the leaf level involving quantification of photosynthesis and plant stress from the measured spectra and the isolation and spectral characterization of plant biochemicals and the determination of their variation in different environments. As much as by direct development of these questions with modeling or experimentation, the field is advancing as results and experience from other related fields are brought in.

b. Global Ecology

Work in this field has continued to involve modeling. Carbon dioxide cycling models have been expanded to include effects of continental margins, seasonality effects based on temperature, and exchange across the air-sea interface. Remote sensing technology has been applied to a variety of studies on wild-fires, malaria and other vector-borne diseases, biomass estimation and

pollution control. Experiments in temperate and tropical rain forests have examined nutrient cycling, particularly nitrogen. Forest-level estimations of photosynthesis based on airborne measurements of CO_2 have been undertaken and appear promising.

Controlled Ecological Life Support Systems

a. Closed Plant Growth Systems

Primary recent work has stressed modeling of complete systems and analysis of system characteristics and control points in detail. Currently the emphasis is being placed on developing models to control these systems. Such control models operate to manipulate the chamber environmental conditions so as to affect the physiology of the plants to yield the desired products (i.e., revitalized air, potable water, food, etc.). In addition, modelling serves as a means to anticipate any problems that could occur in a chamber.

Development of laboratory and flight hardware for experimentation and small-scale plant production has been rapid and extensive with versions appearing from several European and US efforts. A number of large-scale closed and semi-closed plant growth chambers have come on line or are in development. Progress in nutrient delivery systems and in lighting theory has been encouraging and suggests that productivity on a volume basis may be markedly improved. Important improvements in lighting using LED lamps of defined spectral wavebands are directing new work on light delivery arrays. The development of bioreactors for single-cell plant issues and algae has focused largely on operational designs and testing.

Experimental work has largely examined maximization of productivity and food value in the candidate plant species. Plant physiology studies specific to closed and space environments have been extended by a wealth of physiological and biochemical data that appeared on the effects of environmental stresses and toxicities likely to occur in closed systems. Relevant work included plant-plant interactions, build-up of problematic organics and inorganics, and production of phytoallexins and other biochemicals in response to microbial and fungal attacks. Continuing work in plant nutrition will allow development of more balanced nutrient solutions, ones less likely to result in build-up to toxic levels of minor components.

b. Recycling and Waste Management

Recent experimental work in this area has addressed primary treatment of solid and dissolved materials by high pressure wet oxidation near the critical point. It now appears possible to recover nitrogen as ammonia rather than as molecular nitrogen. This finding may remove the need for nitrogen-fixing microorganisms or a chemical method to produce biologically available nitrogen. Research has been initiated to assess the quality of transpiration water from plants and the use of plants as biofilters for waste water streams.

The majority of work, however, has focused on describing waste streams and developing computer model systems for test simulations. These models have included both physical/chemical and biological methods for primary treatment and recovery of materials. Tertiary treatment of the recycled water ("polishing") has appeared as a problem requiring attention, as is shown by the Soviet experience with heavy metal contamination of recycled water. Attention has also been drawn to the potential problems of the microflora that associate with these systems.

Spacecraft Ecology

Recent work has begun to address issues of the total spacecraft ecological system, which includes humans, plants, animals, and microbial organisms. Primary focus has been on microbial biofilms. It has become apparent that water delivery systems are particularly sensitive to microbial contamination and sloughing of active colonies. Biodegradation of spacecraft hardware, particularly from fungal attack, is of particular concern although active research has not as yet followed.

CHAPTER VII

FLUID AND MATERIALS SCIENCES

The major advantages of microgravity are the elimination of gravity-driven convection, sedimentation and fluidstatic pressure. The feasibility of containerless processing is another feature of interest.

Density gradients in liquids and gases arise wherever temperature or concentration gradients exist. This is the case with any heat treatment and any process involving phase transitions, diffusive transport or chemical reactions. Density-gradients and their corollary, buoyancy-driven convection, are thus present in virtually all fluid systems on Earth, and convection processes of a different kind therefore take place. The effects of convection are seldom predictable with great accuracy; it dominates heat and mass transfer in fluids on Earth in a rather undefined fashion. Consequently convection limits the control of numerous processes such as crystallisation, and it also prohibits the execution of defined model experiments for testing theoretical models. Under microgravity conditions gravity-driven convection is virtually eliminated, so that unique conditions for a new generation of experimental research in fluid and materials sciences become available.

Phenomena of fluid dynamics can be investigated in space without the interference of gravity-driven convection. Results from such studies are expected to provide important feedback for the testing and development of theories describing three-dimensional laminar oscillatory and turbulent flow generated by various driving forces.

In space diffusion-controlled transport conditions in fluids can be achieved. This has been demonstrated with a variety of mass diffusion experiments, whereby exceptionally precise data on self-diffusion, hetero-diffusion and thermo-transport have been obtained.

Crystallisation is a problem of controlled heat and mass transfer, and microgravity is therefore of great interest for the solidification of metals and alloys and for crystal growth. All crystal growth processes involving melts, solutions and vapours also involve thermal and concentration gradients. Experiments under microgravity conditions have yielded some very promising results: semiconductor crystals which were grown from the melt proved to be chemically homogeneous; so-called dopant striations, which are caused by convective disturbances, were absent. Crystals with exceptionally low defect density were grown from aqueous solutions.

Crystals grown from the vapour phase had high structural perfection; the growth rate was considerably increased. The growth of mercuric iodide, which is of industrial interest as a room temperature gamma-ray detector, was highly successful. One of the most exciting projects is the crystallisation of proteins. It is estimated that there exist about one million of these substances, yet only about 100 have had their molecular structure unravelled. The bottleneck is the difficulty of crystallising sufficiently large (order of 1 mm) and sufficiently perfect samples for X-ray diffraction analysis. There are clear experimental indications that the crystallisation of proteins is considerably enhanced in space. Very recent experiments have yielded a variety of protein crystals of a quality much superior to what could be obtained on the ground.

In space the behaviour of mixtures of liquids with gases and solids can be investigated without sedimentation causing separation of the components according to their densities. One can prepare composites such as high porosity alloys or particle and fibre dispersions which cannot be obtained on the ground.

The absence of fluidstatic pressure together with the lack of gravity-driven convection provides optimal conditions for the investigation of capillarity phenomena, phase transitions, and critical point phenomena in fluids. As the critical point is approached, the thermodynamic transport and structural properties show anomalies. Furthermore, the compressibility of fluids increases by orders of magnitude and a fluid is therefore compressed under its own weight. The fluid is stratified according to density, and homogeneous bulk samples needed for investigating phenomena near the critical point cannot be obtained on Earth.

In the absence of gravity one can position and manipulate large volumes of high temperature melts without containers. Containerless processing is of interest since crucibles can be the source of contamination, heterogeneous nucleation, and mechanical stress. So far very few microgravity experiments on glass formation have been undertaken. There is interest in studying undercooling, nucleation, and the formation of metastable phases in a containerless mode.

Combustion is an example where all of the features of microgravity come to bear. This involves complex chemical reactions with large temperature and concentration gradients and, therefore, with strong convection. Microgravity offers the opportunity to investigate combustion phenomena under diffusion-controlled conditions.

CHAPTER VIII

SATELLITE DYNAMICS

The most important achievements in the field of the orbital determination and analysis are summarized below:

1. **Accomplishment of the Voyager Mission**

Successful accomplishment of the Voyager mission - the Voyager 2 flyby of the planet Neptune on August 24, 1989 - was to the large extent the result of the high precision orbit prediction and control. After more than 12 years of travel in interplanetary space the spacecraft was directed to its aim with an error of some tens of km, which compared to the length of the trajectory gives a relative accuracy of about the 10^{-8}. This success is due to an excellent performance of the tracking and control system but also to the inventive gravity assisted orbital solution which enabled the visiting of the four great planets during the one single mission.

2. **Permanent service of the determination of the Earth Rotation Parameters based on the observation of the orbital motion of the satellite LAGEOS**

The International Earth Rotation Service (IERS) has developed into a routine service and provides regularly data to the scientific and technical community. The principal output of this service is based on the monitoring of the orbital motion of the satellite LAGEOS by means of laser ranging. The coordinates of the pole and the Earth rotation rate are determined at 5 day intervals with an accuracy of +/- 1 milliarc second and +/-0.1 millisecond respectively. The tracking precision is about +/- 3 cm and the accuracy of the mathematical modelling of the force perturbations is of the order of millimeters.

3. **Preparation of the new space missions oriented to the Earth research**

A number of new projects is in preparation. They are intended for research on the Earth's dynamics and kinematics which requires very precise orbit prediction and determination. The problems which are under consideration concern the optimal exploitation of available and designed tracking systems, tracking stations dislocation, covariance analysis and data handling. These studies contribute to the theory and practical application of geodesy and celestial mechanics. The next mission with precise orbital requirements will be the Earth Resources Satellite - 1 scheduled for launch in 1990.

CHAPTER IX

SPACE RESEARCH IN DEVELOPING COUNTRIES

Recognizing the need for promoting space research in Less Developed Countries (LDC), COSPAR constituted this Panel in 1983. During the COSPAR Plenary at Graz, Austria in 1984 the Panel organized a workshop to bring concerned scientists together, make presentations on national programmes and plans as well as difficulties and needs, and to chalk out a plan of action. The Workshop was co-sponsored by the United Nations and the Committee on Science and Technology in Developing Countries (COSTED). The alliance continues. The Panel made a proposal to ICSU for funds for supporting these activities, and since 1986 the Panel has received modest annual grants.

One important activity of the Panel so far is to organize a Workshop at each COSPAR Plenary on topics of interest to LDCs. In 1988 the Panel organized a Workshop on "Atmospheric Research and Infrastructure needed in Developing Countries" in recognition of the current global concerns about long-term trends in global climate and its relevance to LDCs. UN and COSTED were co-sponsors of this Workshop as well. With such joint support we could invite a number of scientists from LDCs and extend to them partial travel/per diem supoort. On the basis of the experience gained so far, the Panel in its working session decided to organize a Workshop on Equatorial Electrojet. Since many LDCs are located in the equatorial regions and since the phenomenon itself is of great scientific interest, this topic is though to be very relevant for the 1990 COSPAR Plenary at The Hague, Netherlands.

The Panel has also continued its programme on financial support to scientists from LDCs with the grant received under the ICSU-UNESCO subvention.

It should be mentioned that a scientist from Mexico spent a few months in the Space Application Centre at Ahmedabad in India to whom the Indian Space Research Organization extended local hospitality. We must recall here that Pakistan has also offered to pay local expenses for a few scientists from LDCs to enable them to spend a few weeks or months in their R & D institutions for space science.

At the invitation of the UN the COSPAR panel and IAF prepared and submitted a document entitled "Approaches that the United Nations might take in Providing Assistance to Developing Countries in Realizing the Benefits of Space Technology". The paper was well received.

ICSU has constituted a Special Committee for the International Geosphere Biosphere Programme (SC-IGBP) for studying Global Change. The SC-IGBP is convinced that the widest participation of LDCs in IGBP is an essential part of the programme. It is also evident that, since the IGBP is a long-term global programme to study changes and trends in change, the techniques of space monitoring will have a tremendous value for IGBP. Recognizing these two factors the COSPAR Panel has been considering ways and means of augmenting the global efforts in IGBP.

The Panel's work over the years has amply demonstrated that it can play a useful part in complementing and supplementing other national and international efforts to promote SRDC. Presently available funds are not adequate to produce significant results.

LIST OF ACRONYMS AND ABBREVIATIONS

AGN	=	Active Galactic Nuclei
AIRS	=	Atmospheric Infrared Sounder
AMRIR	=	Advanced Medium Resolution Imaging Radiometer
AMSU	=	Advance Microwave Sounding Unit
APEX	=	Active Plasma Experiments
APT	=	Automatic Picture Transmission (NOAA, TIROS)
ARCS	=	Argon Release Control Study
ARGOS	=	French Data Collection and Location System (DCLS) on NOAA Satellites
ASEAN	=	Association of South East Asian Nations
ASO	=	Advanced Solar Observatory
ASTRO	=	Pallet of 3 UV experiment of SpacelabMission (NASA)
AVHRR	=	Advanced Very High Resolution Radiometer
AXAF	=	Advanced X-Ray Astrophysical Facility
BATSE	=	Burst and Transient Source Experiment
BBXRT	=	Broad Band X-Ray Telescope
BMFT	=	Bundesministerium für Forschung und Technologie
BUAN	=	Baseline Upper Air Network
CCD	=	Charged Coupled Device
CDAS	=	Command Data Acquisition Station
CDCF	=	Cosmic Dust Collection Facility
CELIAS	=	Charge Element and Isotype Analysis
CIMSS	=	Cooperative Institute for Meteorological Satellite Studies
CIRA	=	COSPAR International Reference Atmosphere
CLOUD	=	Names of Nimbus-7 Cloud Data Set
CNES	=	Centre National d'Etudes Spatiales
CNSR	=	Comet Nucleus Sample Return
COBE	=	Cosmic Background Explorer
COMPTEL	=	Compton Telescope
COSPAR	=	Committee on Space Research
COSTED	=	Committee on Science and Technology in Developing Countries
COSTER	=	Comprehensive Suprathermal and Energetic Particle Analyzer
CRAF	=	Cometary Rendez-vous Asteroid Flyby
CRIT	=	Critical Ionization Test Flight
CRRES	=	Combined Release and Radiation Effects Satellite
CSA	=	Canadian Space Agency
CZCS	=	Coastal Zone Color Scanner
DCP	=	Data Collection Platforms
DMSP	=	Air Force Defense Meteorological Satellite Program (USA)
DPC-SOCC	=	Data Process Center and System Operational Control Center
EGRET	=	Energetic Gamma-Ray Experiment Telescope
EOS	=	Earth Observing System
ERBE	=	Earth Radiation Budget Experiment
ERBI	=	Earth Radiation Budget Instrument
ERNE	=	Energetic and Relativistic Nuclei and Electron Experiment
ERS	=	European Remote Sensing Satellite
ESA	=	European Space Agency
EUV	=	Extreme Ultraviolet
EUVE	=	Extreme Ultraviolet Explorer
EXOSAT	=	European X-ray Observatory Satellite

FGS	=	Fine Guidance System
FIFE	=	First ISLSCP Field Experiment
FIRE	=	First ISCCP Regional Experiment
FIRST	=	High Throughput Heterodyne Spectroscopy Mission (ESA)
FLINN	=	Fiducial Laboratories for an International National Science Network
FOC	=	Faint Object Camera
FOS	=	Faint Object Spectograph
GAC	=	Global Area Coverage
GEOSAT	=	Geostationary Earth-Orbiting Satellite (NASA)
GEWEX	=	Global Energy and Water Cycle Experiment
GGS	=	Global Geospace System
GHRS	=	Goddard High Resolution Spectograph
GLONASS	=	Global Navigational Satellite System
GMS	=	Geostationary Meteorological Satellite (Japan)
GMS-4	=	Geostationary Meterological Satellite Number 4
GOES	=	Geostationary Operational Environmental Satellite (U.S.)
GOLF	=	Global Oscillations at Low Frequencies
GPCP	=	Global Precipitation Climatology Project
GPS	=	Global Positioning System
GRID	=	Gamma-Ray Imaging Device
GRO	=	Gamma-Ray Observatory
GRSFE	=	Geological Remote Sensing Field Experiment
GSFC	=	NASA/Goddard Space Flight Center
GSI	=	Gesemmschaft für Schwerionenforschung MBH
HCN	=	Hydrogen Cyanide
HEIHE	=	Heihe River Field Experiment
HIREGS	=	High Resolution Gamma-Ray and Hard X-Ray Spectrometer
HIRS	=	High Resolution Infrared Radiation Sounder
HRPT	=	High Resolution Picture Transmission (NOAA)
HSP	=	High Speed Photometer
HST	=	Hubble Space Telescope
HUT	=	Hopkins Ultraviolet Telescope (NASA)
IAF	=	International Astronautical Federation
ICE	=	International Cometary Explorer
ICSU	=	International Council of Scientific Unions
IERS	=	International Earth Rotation Service
IGBP	=	International Geosphere-Biosphere Programme
IKI	=	Institute for Space Research (USSR)
IML	=	International Microgravity Laboratory
INSAT	=	Indian National Satellite
IRAS	=	Infrared Astronomical Satellite
IRI	=	International Reference Ionosphere
ISAS	=	Institute of Space & Astronautical Science (Japan)
ISCCP	=	International Satellite Cloud Climatology Project
ISLSCP	=	The International Satellite Land Surface Climatology Project
ISO	=	Infrared Space Observatory
ISTP	=	International Solar Terrestrial Physics Programme
IUE	=	International Ultraviolet Explorer
KAO	=	Kuiper Airborne Observatory

LAC	=	Local Area Coverage
LAGEOS	=	Laser Geodynamic Satellite
LASCO	=	White Light and Spectrometetric Coronagraph
LDC	=	Less Developed Countries
LDEF	=	Long Duration Exposure Facility
LED	=	Light Emmitting Diode
LEO	=	Low Earth Orbit
LL	=	Low Latitude
MAC	=	Middle Atmosphere Co-operation
MAP	=	Middle Atmosphere Programme
MDI/SOI	=	Michelson Doppler Imager
MDUS	=	Mid-range Data Utilization Stations
MEDLAS	=	Mediterranean Laser Project
MOS	=	Marine Observation Satellite
MRSR	=	Mars Rover Sample Return
MSU	=	Microwave Sounding Unit
NASA	=	National Aeronautics and Space Administration
NASDA	=	National Space Development Agency (Japan)
NCRP	=	National Council on Radiation Protection and Measurements
NDVI	=	Normalized Difference Vegetation Index
NESDIS	=	National Environmental Satellite Data and Information Service (NOAA)
NOAA	=	National Oceanic and Atmospheric Administration
NSSDC	=	National Space Science Data Center
OMV	=	Orbital Manoeuvering Vehicle
OLR	=	Outgoing Longwave Radiation
ORFEUS	=	Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer
OSL	=	Orbiting Solar Laboratory
OSSE	=	Gamma-Ray Observatory Scintillation Spectrometer
POES	=	Polar Orbiting Environmental Satellite
PRC	=	People's Republic of China
QBO	=	Quasi-Biennial Oscillation
SAR	=	Synthetic Aperture Radar
SBUV	=	Solar Backscatter Ultraviolet Spectral Radiometer
SC-IGBP	=	Special Committee for the International Geosphere Biosphere Programme
SCOSTEP	=	Scientific Committee on Solar-Terrestrial Physics
SDUS	=	Small-range Data Utilization Stations
SIRTF	=	Space Infrared Telescope Facility
SLR	=	Satellite Laser Ranging
SMM	=	Solar Maximum Mission
SMMR	=	Scanning Multichange Microwave Radiometer
SMY	=	Solar Maximum Year
SOFIA	=	Stratospheric Observatory for Infrared Astronomy
SOHO	=	Solar and Heliospheric Observatory
SOUP	=	Solar Optical Universal Polarimeter
SPOT	=	Satellite pour l'observation de la Terre
SRDC	=	Space Research in Developing Countries (COSPAR Panel)
SSM/I	=	Special Sensor Microwave/Imager
SSM/T	=	Special Sensor Microwave/Temperature Sounder
SSU	=	Stratospheric Sounding Unit
STEP	=	Solar-Terrestrial Energy Program
STIP	=	Solar Travelling Interplanetary Phenomena
STIS	=	Space Telescope Imaging Spectrograph (NASA)
STSP	=	Solar Terrestrial Science Programme
SUMER	=	Solar Ultraviolet Coronograph Spectrometer
SWAN	=	Solar Wind Anisotropies

TDRSS	=	Tracking and Data Relay Satellite System
TIR	=	Infrared Telescope (Italy)
TIROS	=	Television and Infrared Observations Satellite
TM	=	Thematic Mapper
TOVS	=	TIROS Operational Vertical Sounder
TYCHO	=	Experiment using altitude measurement system of Hipparcos Satellite to obtain astrometric and photometric data for a large number of stars
UIT	=	Ultraviolet Imaging Telescope (NASA)
UN	=	United Nations
UNESCO	=	United Nations Educational, Scientific and Cultural Organization
URSI	=	International Union of Radio Science
UV	=	Ultraviolet
VIRGO	=	Variability of Solar Irradiance
VLBA	=	VLBI Array
VLBI	=	Very Long Baseline Interferometry
VOIR	=	Venus Orbiter Radiometer
VSOP	=	VLBI Space Observatory Programme
WCRP	=	World Climate Research Program
WEFAX	=	Weather Facsimile
WF/PC	=	Wide Field/Planetary Camera
WMO	=	World Meteorological Organization
WUPPE	=	Wisconsin Ultraviolet Photo-Polarimeter Experiment (NASA)
XMM	=	X-ray Multi-Mirror Observatory
XTE	=	X-Ray Timing Explorer